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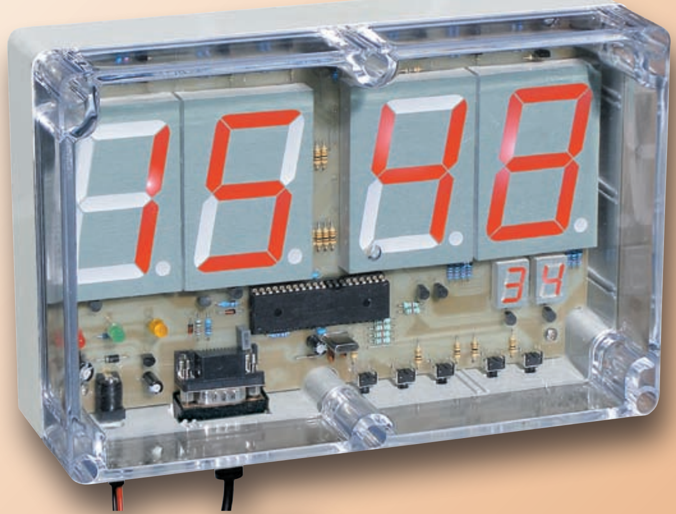
WIN A MICROCHIP mTouch Capacitive Evaluation Kit



6-DIGIT GPS CLOCK – PART 1

A dead-accurate timepiece set by GPS atomic clocks

THE µCURRENT

- Overcomes inherent limitations in commercial designs
- Precision current adaptor for digital multimeters
- Resolution down to just tens of picoamps
- Compact, battery powered and easy to use

DIGITAL AUDIO OSCILLATOR

A handy project to test audio equipment in the field and workshop

PLUS

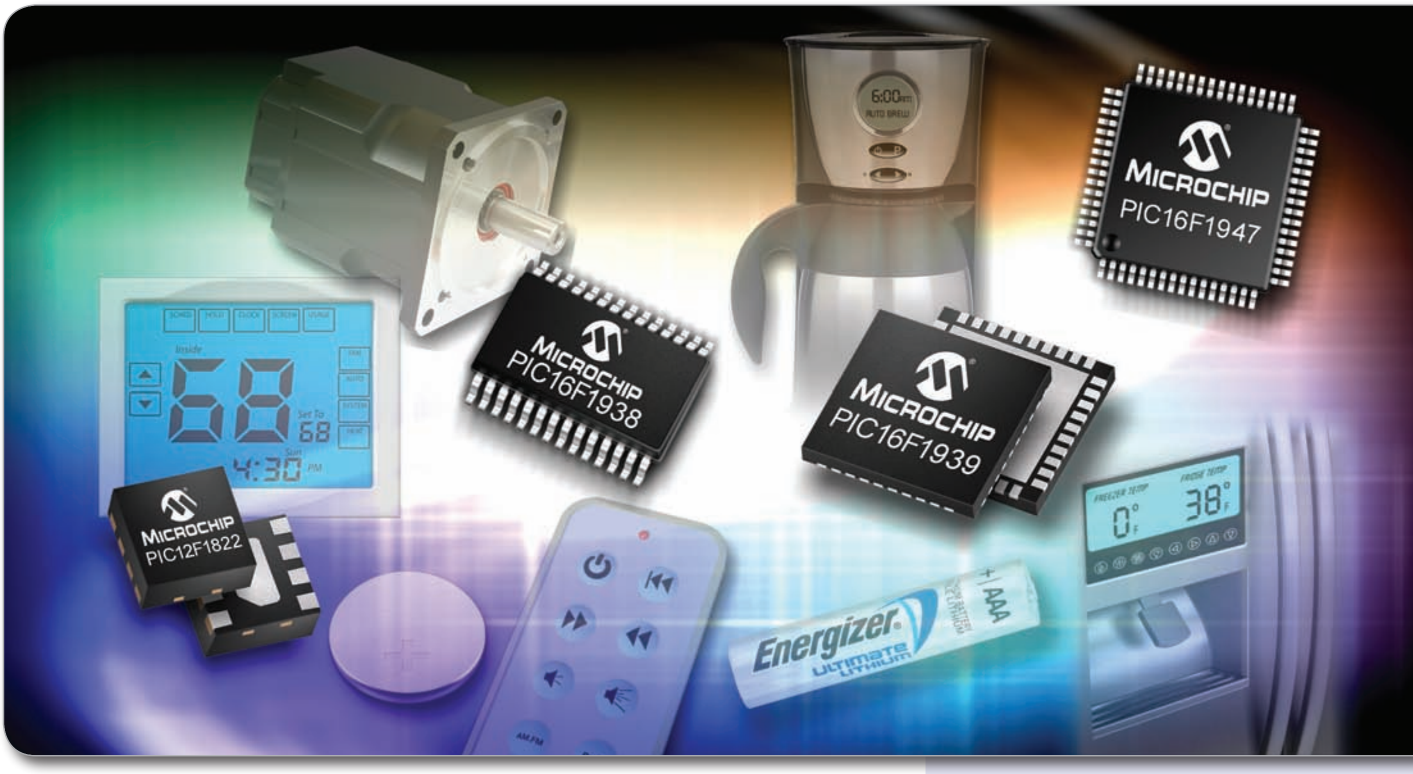
TEACH-IN 2011 – PART 7

A not-to-be missed introduction to the 555 chip, monostable and astable designs – timer circuits

$8.99US £4.25UK
MAY 2011 PRINTED IN THE UK
05

Low-Power Microcontrollers for Battery-Friendly Design

Microchip Offers Lowest Currents for Active and Sleep Modes



Extend the battery life in your application using PIC® microcontrollers with nanoWatt XLP Technology and get the industry's lowest currents for Active and Sleep modes.

Microchip's new peripheral-rich PIC12F182X, PIC16F182X and PIC16F19XX families offer active currents of less than 50 µA and sleep currents down to 20 nA. These products enable you to create battery-friendly designs that also incorporate capacitive touch sensing, LCD, communications and other functions which help differentiate your products in the marketplace.

Microchip's Enhanced Mid-range 8-bit architecture provides up to 50% increased performance and 14 new instructions that result in up to 40% better code execution over previous-generation 8-bit PIC16 MCUs.

PIC12F182X and PIC16F182X families include:

- Packages ranging from 8 to 64 pins
- mTouch™ capacitive touch-sensing
- Multiple communications peripherals
- Dual I²C™/SPI interfaces
- PWM outputs with independent time bases
- Data signal modulator

PIC16F19XX family includes:

- mTouch capacitive touch-sensing
- LCD drive
- Multiple communications peripherals
- More PWM channels, with independent timers
- Up to 28 KB of Flash program memory
- Enhanced data EEPROM
- 32-level bandgap reference
- Three rail-to-rail input comparators

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2. Download the Low Power Tips 'n Tricks
3. Order samples and development tools
   www.microchip.com/XLP

PIC16F193X 'F1' Evaluation Platform - DM164130-1

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VOL. 40. No 5 May 2011

EPE EVERYDAY PRACTICAL ELECTRONICS

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Our June 2011 issue will be published on Thursday 12 May 2011, see page 80 for details.

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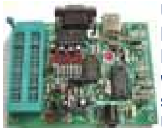
PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU120) £19.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

NEW! USB & Serial Port PIC Programmer

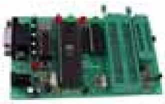


USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

NEW! USB 'All-Flash' PIC Programmer

USB PIC programmer for all 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows XP Software. ZIF Socket and USB lead not incl.
Assembled Order Code: AS3128 - **£49.95**
Assembled with ZIF socket Order Code: AS3128ZIF - **£64.95**

ATMEL 89xxxx Programmer

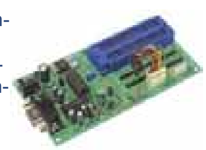


Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

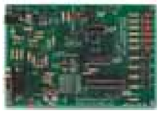
Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board



Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board

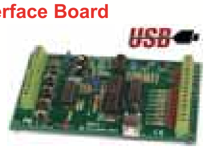


The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU445 £7.95

USB Experiment Interface Board



5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£38.95**
Assembled Order Code: VM110 - **£64.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£49.95**
Assembled Order Code: AS3180 - **£59.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£19.95**
Assembled Order Code: AS3145 - **£26.95**
Additional DS1820 Sensors - **£3.95 each**

Remote Control Via GSM Mobile Phone

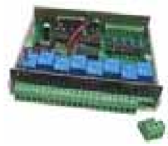
Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£13.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£74.95**
Assembled Order Code: AS3140 - **£89.95**

8-Ch Serial Port Isolated I/O Relay Module



Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£69.95**
Assembled Order Code: AS3108 - **£84.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£59.95**
Assembled Order Code: AS3142 - **£69.95**

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU445). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£34.95**
Assembled Order Code: AS3153 - **£44.95**

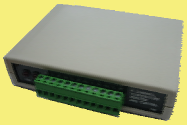
Telephone Call Logger

Stores over 2,500 x 11 digit DTMF numbers with time and date. Records all buttons pressed during a call. No need for any connection to computer during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. Supply: 9-12V DC (Order Code PSU445).
Kit Order Code: 3164KT - **£44.95**
Assembled Order Code: AS3164 - **£59.95**

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board



4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£69.95**
Assembled Order Code: AS3190 - **£84.95**

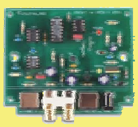
40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£27.95**
Assembled Order Code: AS3188 - **£36.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£37.95**
Assembled Order Code: AS3187 - **£47.95**

Video Signal Cleaner



Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£32.95**
Assembled Order Code: VM106 - **£49.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

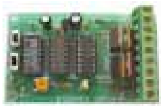
Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)

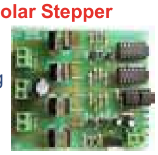
Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£18.95**
Assembled Order Code: AS3067 - **£26.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver



Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£15.95**
Assembled Order Code: AS3179 - **£22.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£23.95**
Assembled Order Code: AS3158 - **£33.95**

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£22.95**
Assembled Order Code: AS3166v2 - **£32.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£14.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more motor controllers

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Order Code EPL500 - **£179.95**
Also available: 30-in-1 **£19.95**, 50-in-1 **£29.95,** 75-in-1 **£39.95** £130-in-1 **£44.95** & 300-in-1 **£69.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Two-Channel USB Pc Oscilloscope

This digital storage oscilloscope uses the power of your PC to visualize electrical signals. Its high sensitive display resolution, down to 0.15mV, combined with a high bandwidth and a sampling frequency of up to 1GHz are giving this unit all the power you need.
Order Code: PCSU1000 - **£399.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~£189.95~~ **£169.95**

See website for more super deals!

No.1 FOR KITS

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EVERYDAY PRACTICAL ELECTRONICS

FEATURED KITS

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested down under.
All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

MAY 2011

240V 10A DELUXE MOTOR SPEED CONTROLLER KIT

KC-5478 £36.25 plus postage & packing
The deluxe motor speed controller kit allows the speed of a 240VAC motor to be controlled smoothly from near zero to full speed. The advanced design provides improved speed regulation & low speed operation. Also features soft-start interferences suppression, fuse protection and over-current protection. Kit supplied with all parts including pre-cut metal case.

FEATURED THIS MONTH

Note: Requires UK Mains socket or adaptor.

LOW COST PROGRAMMABLE INTERVAL TIMER

KC-5464 £12.75 plus postage & packing
Here's a new and completely updated version of the very popular low cost 12VDC electronic timer. It is link programmed for either a single ON, or continuous ON/OFF cycling for up to 48 on/off time periods. Selectable periods are from 1 to 80 seconds, minutes, or hours and it can be restarted at any time. Kit includes PCB and all specified electronic components.

• PCB Dimensions: 102 x 42mm
Featured in EPE August 2010

PIR CONTROLLED MAINS POWER SWITCH

KC-5455 £29.00 plus postage & packing
You've seen those lights fitted with PIR detectors that turn on when someone approaches. Well now you can do the same thing with just about any mains-powered device you like including security systems, decorative lighting, fountain pumps or even commercial advertising etc. The system uses a standard PIR to safely turn on 240VAC mains device(s) for an adjustable pre-set period. Kit supplied with case, screen printed PCB, and all electronic components.

Note: Requires UK Mains socket or adaptor.
Featured in EPE April 2011

IMPROVED LOW VOLTAGE ADAPTOR

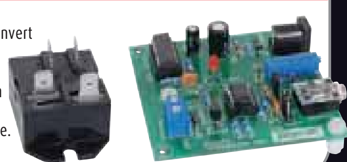
KC-5463 £6.75 plus postage & packing
This handy regulator will let you run a variety of devices such as CD, DVD or MP3 players, digital cameras or even powered speakers from the power supply inside your PC. This unit can supply either 3V, 5V, 6V, 9V, 12V or 15V from a higher input voltage at up to four amps (with a suitable heatsink). Kit includes screen printed PCB and all specified components.

Note: To ensure trouble free 4 amp output, a heatsink with a thermal resistance of 1.4 degrees C per watt, and an input voltage 3VDC above the output voltage is required.

• PCB Dimensions: 108 x 37mm
Featured in EPE November 2007

TEMPMASTER FRIDGE CONTROLLER MK II

KC-5476 £12.00 plus postage & packing
Turn an old chest freezer into an energy-efficient fridge or beer keg fridge. Or convert a standard fridge into a wine cooler. These are just two of the jobs this low-cost and easy-to-build electronic thermostat kit can do without the need to modify internal wiring! Used also to control 12V fridges or freezers, as well as heaters in hatcheries and fish tanks. Short-form kit contains PCB, sensor and all specified components. You'll need to add your own 240V GPO, switched IEC socket and case.



• PCB Dimensions: 68 x 67mm Featured in EPE February 2011

PIC BASED WATER TANK LEVEL METER KIT

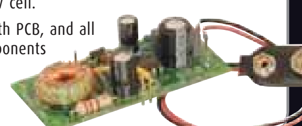
KC-5460 £39.50 plus postage & packing
This PIC-based unit uses a pressure sensor to monitor water level and will display tank level via an RGB LED at the press of a button. The kit can be expanded to include an optional wireless remote display panel that can monitor up to ten separate tanks (KC-5461), or you can add a wireless remote controlled mains power switch (KC-5462) to control remote water pumps. Kit includes electronic components, case, screen printed PCB and pressure sensor.

Also available:
KC-5461 - Remote display kit £31.00
KC-5462 - UHF remote mains switch £36.25
Featured in EPE May 2010

3V TO 9V DC TO DC CONVERTER KIT

KC-5391 £6.00 plus postage & packing
This great little converter allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or Alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no-time! You can use any 1.2-1.5V cells you desire. Imagine the extra capacity you would have using two 9000mAh D cells in replacement of a low capacity 9V cell.

• Kit supplied with PCB, and all electronic components
Featured in EPE June 2007



433MHZ REMOTE SWITCH KIT

KC-5473 £16.50 plus postage & packing
Suitable for remote control of practically anything up to a range of 200m. The receiver has momentary or toggle output and the momentary period can be adjusted. Up to five receivers can be used in the same vicinity. Short-form kit contains two PCBs and all specified components.

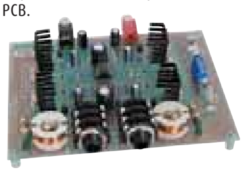
• Extra transmitter kit: KC-5474 £8.50
• PCB Dimensions:
  Tx: 85 x 63mm
  Rx: 79 x 48mm
Featured in EPE January 2011

AUDIO KITS

Stereo Headphone Distribution Amplifier

KC-5417 £12.75 plus postage & packing
Enables you to drive up to two stereo headphones from any line level (1 volt peak to peak) input. The circuit features a facility to drive headphones with impedances from about 8-600 ohms. Kit includes all specified board components and quality fibreglass tinned PCB.

• Power Supply to Suit: KC-5418 £7.50
• PCB Dimensions: 134 x 103mm
Featured in EPE November 2009



Studio 350 - High Power Amplifier

KC-5372 £63.50 plus postage & packing
The studio 350 power amplifier will deliver a whopping 350WRMS into 4 ohms or 200WRMS into 8 ohms. It offers real grunt using a high power MJ21193/4 transistor and is super quiet with a very low signal to noise ratio and harmonic distortion. This kit is supplied in short form with PCB and electronic components. Kit requires heatsink and (+/-) 70V power supply as described in instructions. See website for more specifications.
Featured in EPE October/November 2006

45 Second Voice Recorder Module

KC-5454 £16.00 plus postage & packing
This kit has been improved and can now be set up easily to record two, four or eight different messages for random-access playback or a single message for 'tape mode' playback. Also, It also now provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9-14V DC. Supplied with silk screened and solder masked PCB and all electronic components.

• PCB Dimensions: 120 x 58mm
Featured in EPE February 2011

Jaycar Electronics

Freecall order: 0800 032 7241

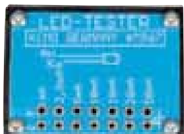
Test & Lighting Kits for Electronic Enthusiasts

LED TESTER MODULE

AA-0272 £6.25 plus postage & packing

This basic but essential tool allows you to check the function, brightness, colour and polarity of all kinds of light emitting diodes (LED). The LED to be tested plugs into the front panel at the current you wish to test it with. Two 10mA positions have been included on this multi-LED tester so that comparisons between two LEDs can be made simultaneously.

- Requires 9V Bolt
- Test currents: 1mA, 2.5mA, 5mA, 10mA, 20mA,50mA
- Dimensions: 58 x 44 x 25 mm



LED BATTERY VOLTAGE INDICATOR

KA-1778 £3.75 plus postage & packing

This tiny circuit measures just 25mm x 25mm and will provide power indication and low voltage indication using a bi-colour LED. The LED will be green when above the set point & red when below. The set point is adjustable using a trim-pot. The circuit is suitable for equipment powered from about 6-30VDC. With a simple circuit change, the bi-colour LED will produce a red glow to indicate that the voltage has exceeded a preset value.

- PCB, bi-colour LED and all specified electronic components supplied

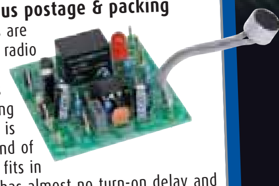
KIT OF THE MONTH

"Minivox" Voice Operated Relay

KC-5172 £6.00 plus postage & packing

Voice operated relays are used for 'hands free' radio communications and some PA applications etc. Instead of pushing a button, this device is activated by the sound of a voice. This tiny kit fits in the tightest spaces, has almost no turn-on delay and can be used to turn on only low power devices. 12VDC @ 35mA required. Kit is supplied with PCB electret mic, and all specified components.

- PCB: 47 x 44mm

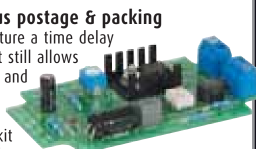


Communicate Hands Free!

COURTESY INTERIOR LIGHT DELAY KIT

KC-5392 £7.50 plus postage & packing

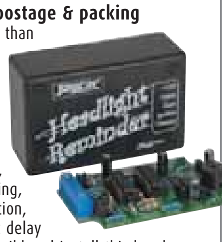
Many modern cars feature a time delay on the interior light. It still allows you time to buckle up and get organised before the light dims and finally goes out. This kit provides that feature for cars which don't already provide it. It has a soft fade out after a set time has elapsed, and features much simpler universal wiring than previous models we have had.



HEADLIGHT REMINDER FOR CARS

KC-5317 £10.25 plus postage & packing

Nothing is more frustrating than getting into your car early in the morning, only to discover that you had left your headlights on the night before, running your car's battery flat. Features include a modulated alarm, ignition and lights monitoring, optional door switch detection, time-out alarm and a short delay before the alarm sounds. Build and install this hassle saving kit and enjoy a feature in your car that many luxury vehicle owners have long taken for granted.



LUXEON STAR LED DRIVER KIT

KC-5389 £11.00 plus postage & packing

Luxeon high power LEDs are some of the brightest LEDs available in the world. They offer up to 120 lumens per unit, and will last up to 100,000 hours! This kit allows you to power the fantastic 1W, 3W, and 5W Luxeon Star LEDs from 12VDC. This means that you can take advantage of what these fantastic LEDs have to offer, and use them in your car, boat, or caravan.

- Kit supplied with PCB, and all electronic components

TRANSISTOR TESTER

KA-1119 £10.25 plus postage & packing

Have you ever unsoldered a suspect transistor only to find that it checks OK? Troubleshooting exercises are often hindered by this type of false alarm. You can avoid these hassles with the In-Circuit Transistor, SCR and Diode Tester. The kit does just that, test drives without the need to unsolder them from the circuit! Kit includes a jiffy box, battery, electronic components and a panel showing truth table for device checking.

Don't just sit there BUILD SOMETHING!

5 METRE IR LIGHT BEAM

KG-9094 £5.50 plus postage & packing

With a range of about 5 metres, this kit will indicate using an LED when a person or object interrupts the infrared light beam. Use it across a doorway or across an assembly line. Kit supplied with Kwik Kit PCB, infrared transmitter/receiver diodes, and all electronic components.

- 9-12VDC operation
- PCB Dimensions: 58 x 45mm

FLICKERING FLAME LIGHTING

KC-5234 £6.25 plus postage & packing

This lighting effect uses a single 20 watt halogen lamp (the same as those used for domestic down lights) to mimic its' namesake. Mounted on a compact PCB, it operates from 12VDC and uses just a handful of readily available components. Use it for stage performances or for unique lighting effects at home.

- Kit includes 20W halogen lamp
- PCB plus electronic components
- Includes ceramic base for halogen lamp (SL-2735)

DIGITAL MULTIMETER KITS

Digital Multimeter Kits

KG-9250 £9.00 plus postage & packing

Learn everything there is to know about component recognition and basic electronics with this comprehensive kit. From test leads to solder, everything you need for the construction of this meter is included.

- Dimensions: 67(W) x 123(H) x 25(D)mm

Low Capacitance Adaptor for DMM Kit

KC-5493 £12.75 plus postage & packing

Many modern multimeters come with capacitance ranges, but they're no good for very small values. This kit is a nifty little adaptor that allows a standard digital multimeter to measure very low values of capacitance from less than one picofarad to over 10nF. It will allow you to measure tiny capacitors or stray capacitances in switches, connectors and wiring. The kit is complete with PCB, components and case. All you'll need is a 9V battery and just about any modern DMM.

12V LIGHT OPERATED RELAY

KG-9090 £9.25 plus postage & packing

Operate as a twilight on/off switch or as a light trigger relay from 12 volts, this versatile project triggers a 6 amp relay when the light intensity falls below an adjustable threshold. Turn lights on around the house when it goes dark or trigger an alarm when a light is switched on. Kit supplied with Kwik Kit PCB, relay and all electronic components.

- PCB Dimensions: 55 x 27mm

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EVERYDAY PRACTICAL ELECTRONICS

When it comes to safety, prepare for the worst!

The terrible events in Japan, where disaster has followed disaster, are a timely reminder that risk and its management are an unavoidable fact of life. While the initial priority is clearly to help the affected, it is also important to try and learn what went wrong, and then to act on whatever conclusions are drawn.

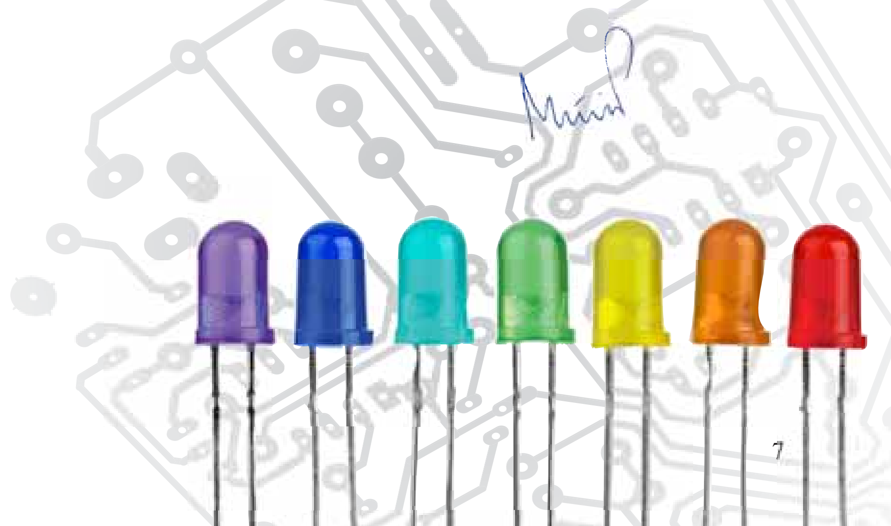
A recent article in the *Washington Post* made some interesting observations about risk. It pointed out that much of our behaviour and many of our 'systems are not operated as if things could go wrong. They operate as if everything will go right.' In other words, 'fingers crossed'.

This becomes especially interesting for very rare events that could have catastrophic consequences. The United States Department of Energy, Oak Ridge National Laboratory warned last autumn about the potential effects of an electromagnetic pulse (EMP), caused by a solar flare that could knock out the electrical grid for up to 130 million Americans. While rare, these events can and do happen. A solar storm damaged neighbouring Quebec's power system in 1989, causing a blackout that affected six million people. The issue then, is how far should we go to protect against such low-probability, high-consequence hazards?

Oak Ridge highlighted that paying now is a lot cheaper than paying later. It stated, 'The cost of damage from the most extreme solar event has been estimated at one to two trillion dollars, with a recovery time of four to ten years, while the average yearly cost of installing equipment to mitigate an EMP event is estimated at less than 20 cents [12 pence] per year for the average residential customer.'

The basic conclusion is hope for the best, but prepare for the worst – it really is the cheapest, safest route in the long run. So, how does this affect us? Many of you will use mains electricity in your projects and designs, and despite knowing better, we all take the odd chance, poking around inside 'live' circuits, or perhaps simply replacing a repeatedly blown fuse without investigating why its operated. In other words, we take short cuts and tell ourselves that we know what we are doing, or that we've been fine so far, so what's there to worry about?

The answer is simple – the individual risk of each event may be low, but the level of harm of just one accident could be very high. So please, be safe in our hobby, and when it comes to mains electricity, always assume the worst could happen – that way, it is so much less likely to happen!



NEWS

A roundup of the latest Everyday News from the world of electronics

3D TV – *the BBC gets serious* by Barry Fox

Japanese giant Panasonic has lead the rush to 3D TV, and at the company's annual trade convention – held this year at the Excel conference centre in Docklands – the company launched yet more 3D TVs, along with 3D Blu-ray players and recorders. Unfortunately, the recorders will be of limited use because they cannot be digitally connected to a Sky HD box to capture Sky's 3D channels.

If the BBC starts broadcasting free-to-air 3D by Freeview or Freesat, there might be an option to record. But a panel session on 3D, chaired by veteran broadcast industry consultant Chris Forrester, raised no hopes that this will happen soon.

The BBC, it emerged, is investing heavily in the production of 3D programmes, but these will initially be seen only in cinemas.

Explained Amanda Hill MD BBC Worldwide, the BBC division which is making the 3D programmes for sale around the world: 'The theatric case for 3D is proven. It's three-times more profitable. That's why BBC Worldwide is leading on theatric release. You learn more by getting things wrong. People are cutting their teeth on theatric release. It's only difficult to get funding for bad content. That's why BBC Worldwide is focussing on natural history'.

The BBC and a range of financing partners is spending \$65m on *Walking with Dinosaurs - 3D*, due for completion in 2012, with distribution by Fox.

'Children like dinosaurs because they represent safe danger' says Hill. 'So we are remaking the 1999 programme in 3D. In 2013, BBC Worldwide will spend \$20m on shooting live adventure in Africa in 3D.'

Jim Chabin, president, International 3D Society, assured that a standard for active shutter glasses, and universal multi-standard glasses that can view any set, were close. 'Just about every fashion house is working on cool sunglasses that also work as 3D glasses. People are comfortable with fashion accessories like wraparound glasses for skateboarders.'

Chabin reminded that silent movie star Harold Lloyd had dreamed of making movies in 3D.

'Spectacular events like sport are not a good business model' he warned. 'They are one-time events. Gamers are driving adoption. When *Call of Duty* came out, Xpand sold a hundred thousand pairs of active shutter glasses in seven days. It took them a while to figure out what was happening.'

Professor Hans Strasburger, who researches perception at the University of Munich, is obviously very enthusiastic about 3D.

'It's a myth that glasses are a nuisance' he argued. 'It's like getting a new pair of correction spectacles. It takes you half an hour to adapt. I am surprised there is any discussion.'

'The work on how many people cannot watch 3D is unreliable. It's between 5 and 10%, let's say 8%. There are two main reasons. One is squint, where the eyes are correctly aligned. The brain does not develop the right neurons. Or it can happen when one eye is much more short-sighted than the other. The first three to six months of a child's life are the most important in developing correct vision. Take your baby to the eye doctor for a check. Otherwise problems can go unnoticed until they go to see *Avatar* and wonder what everyone is talking about.'

'It's also unclear why some people get headaches from 3D. It could be caused by problems with convergence. But the idea that children are at risk from 3D is pure myth.'

Jim Chabin suggests: 'One theory is that people who are susceptible to motion sickness may get the same problem with 3D, especially if there is a lot of horizontal motion on screen.'

Says Amanda Hill: 'Usually it's because the 3D effect is too strong and the images on screen are too far apart. That's why Directors take off their glasses and look at the double image.'

Ironically, this warning followed a demonstration of 3D on a huge Panasonic plasma screen, which featured so many exaggerated effects, such as objects thrown at the audience, that several people had to take off their glasses to spare their brains the strain of viewing.

The panel of experts was stumped on one question though. How will families cope with the likely situation that some people in the living room want to watch the TV in 3D while others want or need to watch in 2D and see double images on screen?

Professor Strasburger suggests: 'They may have to use glasses to shut off one eye.'

Amanda Hill reckons: 'You already get the situation where a child is playing games on a laptop computer screen while parents in the same room are watching TV.'

New energy-saving flip-flop

Toshiba has announced that it has developed a new flip-flop circuit using a 40nm CMOS process that will reduce power consumption in mobile equipment. Tests show that the power dissipation of the new flip-flop is up to 77% less than that of a typical conventional flip-flop, and that it achieves a 24% reduction in total power consumption when applied to a wireless LAN chip.

A flip-flop is a circuit that temporarily stores one bit of data during arithmetic processing by a digital system-on-a-chip (SoC) incorporated in mobile equipment and other digital equipment. Since a typical SoC uses 100,000 to 10 million flip-flops, they are an essential part of an SoC design.

A typical flip-flop incorporates a clock buffer to produce a clock-inverted signal required for the circuit's operation. When triggered by a signal from the clock, the clock buffer consumes power, even when the data is unchanged. In order to reduce this power dissipation, a power-saving design technique called clock gating is widely used to cut delivery of the clock signal to unused blocks. However, after applying the clock gating, the flip-flop active rate, a measure of data change rate per clock, is only 5% to 15%, indicating that there is still plenty of room for further power reduction.

In order to save power, Toshiba changed the structure of the typical flip-flop and eliminated the power-consuming clock buffer. This approach brings with it the risk of data collision between the data writing circuitry and the state holding circuitry in the flip-flop, which they overcame by adding adaptive coupling circuitry to the flip-flop.

A combination of an NMOS transistor and a PMOS transistor, this circuitry adaptively weakens state-retention coupling and prevents collisions. Despite the addition of the adaptive coupling circuitry, overall simplification of the basic flip-flop configuration reduces the transistor count from 24 to 22, and the cell area is less than that of the conventional flip-flop.

Has your office banned Google?

Nearly three quarters of UK workplaces (74%) restrict their employees' access to the Internet, according to a recent survey by office design company Maris Interiors. Seventy-one percent of offices surveyed have a filter for pornographic websites, with 52% of employees unable to access social networking sites such as Twitter or Facebook, and 48% of employees unable to access their personal email.

YouTube was blocked by 30% of employers, and news websites by 27%. Nine percent of offices only allow access to certain specific sites, and 4% only allow staff to use the company's intranet – not even allowing search engines such as Google.

Of those employees who have restrictions in their Internet access, 30% claim this makes their job more difficult – and 82% say it makes their job more boring! Only 6% of employees surveyed said that they actually think it helps with their productivity at work.

Hidden dangers of tomorrow's technology

Sympathetic computers and intelligent shops will soon be commonplace, but a global technological makeover brings new ethical dangers that need to be tackled now, researchers warn.

A major EU-funded research project, led by De Montfort University Leicester (DMU), has been identifying the Information and Communication Technologies (ICTs) likely to emerge in the next 10 to 15 years.

In the near future, our world is set to be transformed by some familiar and not so familiar technologies.

Prof Bernd Stahl, head of DMU's Centre for Computing and Social Responsibility and the project coordinator, said: 'Ethical issues of information technology are already a normal part of our everyday life and media discussions. Think of governments losing data, record companies suing file sharers or patients accessing their medical files.'

In the future, information technologies will become even more widespread and will record new types of data. This will raise a large number of ethical questions that we currently do not even think about.

Computers that can recognise our emotions is one of the areas set to become more common. Known as 'affective computing', the ability to sense and respond to emotions could transform areas such as gaming and healthcare. For example, games consoles that recognise emotions could wait for emotional cues from players before delivering action at the moment that produces the optimum effect.

A new version of the Internet has the potential to revolutionise many different areas of life, from clothes shops that can recognise customers, identify clothes in their size and offer personalised discounts, to smart dust that can be sprinkled on ski resorts to sense the condition of snow. 'Future Internet' or Internet 3.0 has also been nicknamed the 'Internet of things' as it will become the realm of more than just computers.

These new and developing technologies bring with them huge benefits, but can have unforeseen drawbacks that often only become apparent once they are in use. For example, computers that can recognise human feelings can also be used to manipulate our emotions. This could lead to marketing being tailored to people's moods to encourage them to spend more, and it could also be used by fraudsters to lower people's guards, making them easier targets.

Researchers analysed more than 100 technologies for the project, and as a result have identified a list of 11 ICTs they feel will revolutionise our lives in the near future. They are: affective computing; ambient intelligence; artificial intelligence; bioelectronics; cloud computing; future Internet; human-machine symbiosis; neuroelectronics; quantum computing; robotics; and virtual/augmented reality.

New low-cost, non-volatile DACs

Microchip has expanded its non-volatile digital-to-analogue converter (DAC) product range with the MCP47x6 family of low-power, single-channel DACs. These new DACs feature buffered 8-,10- and 12-bit voltage output options and integrated EEPROM in miniature 2 mm × 2 mm DFN, or 6-pin SOT-23 packages. The DACs will enable designers to develop more creative designs, while meeting targets for reducing size and cost in consumer applications such as wireless microphones and MP3-player accessories, and in industrial applications including motor control, flow measurement, temperature control and light control.

The integrated EEPROM enables DAC settings to be recalled at power up, for added system flexibility. The choice of 8-, 10- or 12-bit resolution provides flexibility to achieve the right balance of functionality and cost, while the buffered output voltage allows a selectable gain of 1 or 2, and provides a rail-to-rail output. Low power consumption of 210µA extends battery life, and the small packages enable a reduced footprint on the PCB.

To support rapid development of MCP47x6 DACs, the PICtail Plus Daughter Board (ADM00317), priced at $24.99, incorporates the 8-bit MCP4706, 10-bit MCP4716, and 12-bit MCP4726. The board allows a connection to either the Explorer 16 Starter Kit (DV164033) for 16-and 32-bit PIC microcontrollers (MCUs), or the PICkit Serial Analyzer (DV164122), for reading and writing to the DAC registers using the PICkit Serial Analyzer PC software.

Small volume speciality lubricants for electronics

Newgate Simms Limited has launched a small volume distribution division of the company called Newgate, with a specialist range of synthetic lubricants previously only available to manufacturers and large volume customers.

Now available in small amounts are the 'lube for life' high spec synthetic oils and greases for electronics devices, such as potentiometers, connectors, switches etc.

Newgate's website has been written in a way that tries to demystify the often complex process of selecting the correct lubricant, see: **www.newgateonline.com**

Loudest Alarm Clock?

Recently launched, the Amplicom TCL 200 is, at 90 decibels, claimed to be one of the loudest production alarm clocks on the planet. The ultimate alarm clock for heavy sleepers is also ideal for people with hearing impairments – flashing LED lights and a cordless vibrating pillow pad ensure that anyone will wake up to the TCL 200.

Just how loud is 90dB? It's as loud as a lorry. It's the next best thing to having a Vuvuzela player on your bedside table. And on top of the ear-splitting wake-up call, the Amplicom TCL 200 is packed with the latest technology to help wake people who are deaf or hard of hearing: bright LED lights on the top flash when the alarm goes off and a cordless vibrating pad can be tucked under the user's pillow to ensure there's no chance of snoozing through the alarm.

For the hard of hearing, the Amplicom TCL 200 acts as more than just an alarm clock. You can also hook it up to a telephone to amplify the ring sound. And its controls are very easy to use, with simple push buttons on the front and oversized knobs on the back. The dimmable display also boasts large (3cm high) numbers. See: **www.bootshearingcare.com**

The μCurrent

. . . a precision current adaptor for multimeters

You might not be aware of it, but your digital multimeter is unable to make accurate current measurements in low-voltage circuits because of its ‘burden voltage’. This precision current adaptor solves that problem and greatly improves the measurement accuracy, as well.

By DAVID L JONES

DON’T most multimeters already have current measurement ranges? Well, of course they do. But most multimeters, be they a no-name £5 hardware store ‘throwaway’ model or a £1000 highly-accurate brand-name meter, all suffer from two rather annoying issues with their current measurement ranges – ‘burden voltage’ and reduced accuracy.

The biggest problem with current measurement ranges is burden voltage. This is the voltage that the internal current shunt resistor drops as the circuit’s current passes through it.

The burden voltage is typically specified in millivolts per amps (mV/A). The value will change for different current ranges, so you might have 1mV/A, 1mV/mA and 1mV/μA.

On second thoughts

Normally, you may not give burden voltage a second thought, as like many, you probably think it’s fairly insignificant in most applications. In fact, most people would be hard-pressed to tell you what the burden voltage of their particular multimeter actually is. It’s usually buried away in the user manual, if it’s mentioned at all. Next time you borrow a colleague’s meter, ask them what the burden voltage is, and watch their reaction!

At small displayed currents, the burden voltage is usually not an issue, but at larger displayed currents (relative to full-scale) it can be very high, even in the order of several volts! This can often force you to use a higher current range (with a lower-value shunt resistor), with subsequent loss of resolution and (often) accuracy.

You may, in fact, have encountered this many times, with your circuit either not working or ‘playing up’ on too low a current range. That’s the burden voltage at work, starving your circuit of the voltage it needs to function correctly. You usually have no option but to reluctantly switch to a higher current range to lessen the effect.

The problem can also be highlighted with the many 4½-digit or ‘10000 count’ meters on the market. In theory, they allow you to get an extra digit of resolution over a 3½-digit meter. But you may now find yourself trying to measure, for example, 990.0μA on the 1mA range with a burden voltage of just under 1V. Can your circuit really handle a 1V drop?

The burden voltage of a multimeter is determined primarily by the shunt resistor used for measurement. However, on the higher current ranges (mA and A) it also includes the protection fuse resistance and, to a much lesser extent, any switch and test lead contact resistance. Some manufacturers will specify it as a total or just the shunt resistor, or in many cases not mention it at all!

Some meters will specify it as a maximum voltage drop only. For example, ‘300mV max’. In this case, to get the mV/A value, you divide that voltage by the full-scale range current.

Current measurements with low supply rails

The recent trend toward low-voltage microcontrollers and other silicon devices (some operating from as low as 1V or less!) has really highlighted the need for considering the burden voltage when measuring currents. Supplies of 3.3V have been widely used for a long time now and the trend is heading lower.

A common task these days is to measure the accurate ‘sleep’ and operating current of a microcontroller. Indeed, with the lower supply voltages of today’s battery-powered circuits, accurately measuring the supply current has become more critical.

So the industry has changed, but digital multimeters haven’t really kept up with the pace when it comes to accurate current measurement. You may think that multimeters are getting more ‘accurate’ for less cost, but that’s only part of the story.

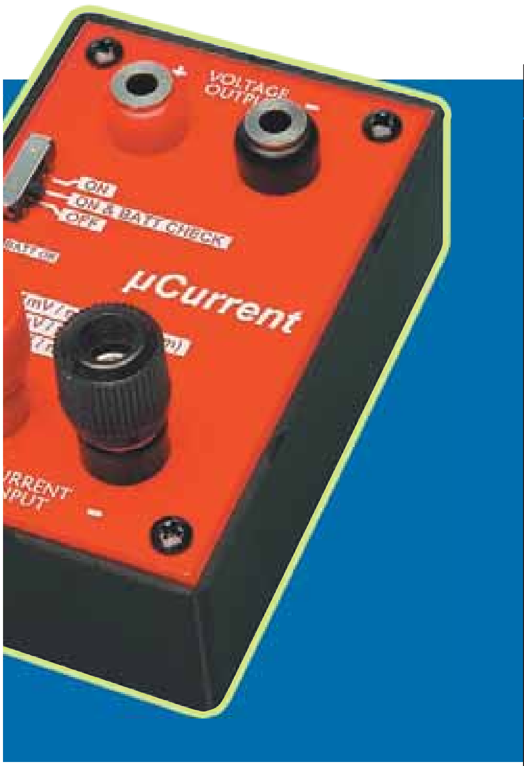


Table 1: Burden voltages for typical multimeters

Multimeter model	Approx cost(£)	Burden voltage (mA range)	Burden voltage (μA range)
Meterman 5XP (3.5-digit)	£40	1V max	300mV max
JayTech QM-1340 (4.5-digit)	£60	5mV/mA	0.11mV/µA
Meterman 30XR	£75	4.6mV/mA	1mV/µA
Protek 506	£110	1mV/mA	1mV/µA
Meterman 37XR (10,000 count)	£150	10mV/mA	1mV/µA
B&K 390A (4000 count)	£240	2V max	500mV max
Fluke 77 series III (3.5-digit)	£250	6 mV/mA	N/A
Fluke 77 series IV (6000 count)	£265	2mV/mA	N/A
Fluke 79 series III (3.5-digit)	£235	11mV/mA	N/A
Fluke 177/179 Series IV (6000 count)	£270	2mV/mA	N/A
Fluke 27	£560	5.6mV/mA	0.5mV/µA
Fluke 80 series V (4.5-digit)	£450	1.8mV/mA	0.1mV/µA
Agilent U1251A (4.5-digit)	£425	1mV/mA	0.1mV/µA
Extech MM570 (500,000 count)	£425	3.3mV/mA	0.15mV/µA
Fluke 289 (50,000 count)	£600	1.8mV/mA	0.1mV/µA
Gossen MetraHit E-XTRA (60,000 count)	£1050	300mV max	150mV max
Fluke 8808A (5.5-digit)	£685	1mV/mA	1mV max
Fluke 8846A (6.5-digit)	£1300	500mV max	15mV max
Keithley 197A Microvolt (5.5-digit)	N/A	300mV max	300mV max

Voltage impact

Let's look at how the supply voltage can impact your current measurement or vice-versa, as the case may be.

Let's say you want to measure the supply current of a chip or circuit taking 200mA using a 4000-count meter on the 400mA range. This is a fairly common scenario, and one you would think would be pretty easy for any multimeter to handle. But maybe not.

A typical high-end 'accurate' multimeter will have a 'low' 1mV/mA burden voltage (about as low as it gets), so this means the meter will drop 200mV across its shunt resistor at 200mA. This represents an almost tolerable 4% (200mV/5V × 100) of a 5V supply voltage.

This may not be a big deal if your supply voltage is spot on 5V, as your chip will get 4.8V and still be within spec. But what if it's only 4.8V? Your chip or circuit will now be getting only 4.6V, which may well be below its operating specifications.

This already shows the limitation of the current range on a typical multimeter. But that's without even considering how the circuit current can differ when you lower the rail by 0.2V.

Let's now say you need to do the same thing on a modern circuit or chip with, say, a 1.2V power supply, ie, the voltage from a single NiMH cell. That same 200mV burden voltage is now a whopping 17% (200mV/1.2V × 100) of the supply voltage. Your circuit may now fail to function correctly and this is clearly not acceptable, not to mention inaccurate.

Think this is only a problem with 'cheap' meters? Well, think again. The Fluke 87-V, probably the most popular high-performance meter available, has a burden voltage of 1.8mV/mA (which is still pretty good). So the above numbers are even worse – a 360mV drop for a 200mA current.

Sure, you can switch up a current range, using the 10A jack, with its burden voltage of say 10mV/A, giving you a very nice drop of only 2mV. But your display is now showing 0.200 or 0.20 instead of 200.0 – you've just lost a valuable digit or two of resolution. The higher 10A current range is likely to be much less accurate than the mA range too!

Let's now take a look at the quoted burden voltage of some typical multimeters – see Table 1. As shown, things can improve a bit with the more expensive meters, particularly on the µA ranges. But an expensive precision meter is by no means a guarantee of a low burden voltage. Even many top-of-the-line bench meters can have unacceptable burden voltages for many applications.

It should be noted that while some meters will have a fixed burden voltage for all mA ranges, others, like the Meterman 30XR have individual specifications for each range; ie, 2mA range = 100mV/mA, 20mA = 13mV/mA and 200mA = 4.6mV/mA.

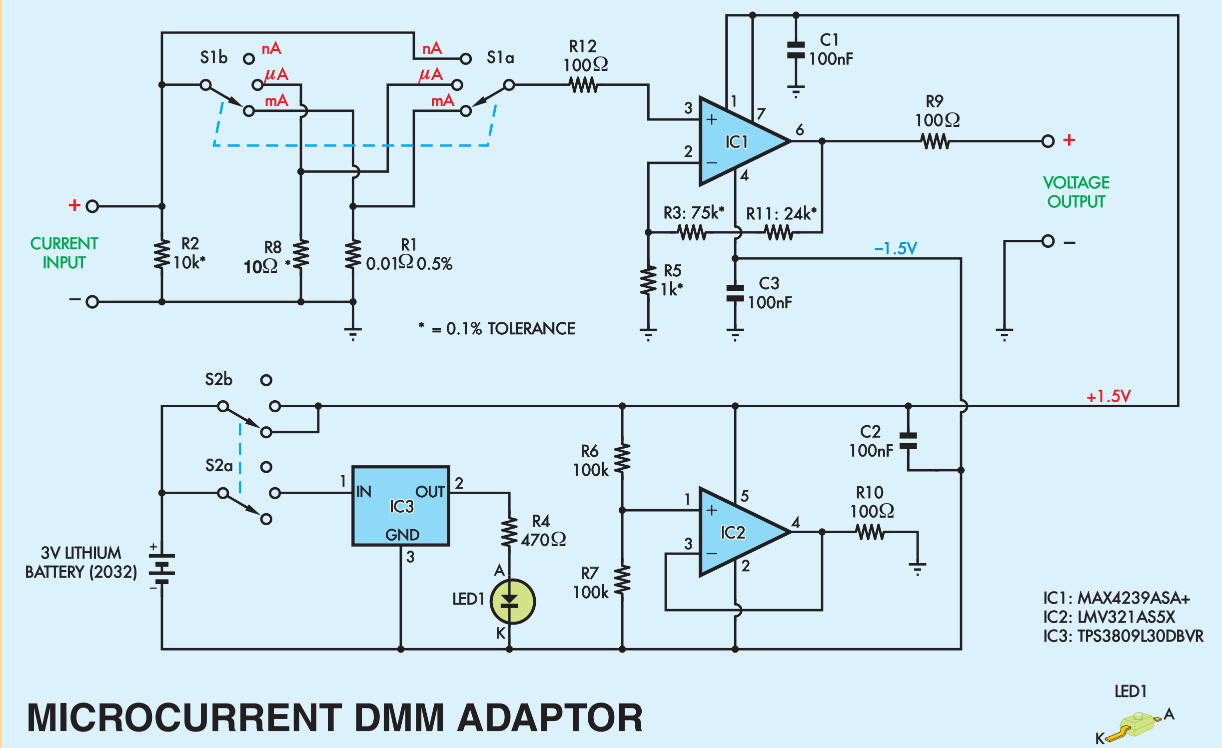


Fig.1: the circuit is based on IC1, a Maxim MAX4239 ultra-low offset/drift, low-noise precision amplifier. IC3 is a voltage monitor, while voltage follower stage IC2 provides a virtual ground reference for the circuit.

Some popular and highly regarded meters like the Meterman 37XR and Fluke 79 are particularly bad on their mA range, an order of magnitude worse than some cheaper meters – so beware. Taking the above example again, the Meterman 37XR would drop a whopping 2V (10mV × 200) on its mA range for 200mA. This will not be much good when your supply voltage is only 3.3V, 5V or even 12V.

And the 37XR is a relatively expensive 10000-count meter that is supposed to be capable of measuring 999.9mA on its 1A range – which it will try to do. But that would be a gigantic 10V drop which the meter itself cannot even handle, so it's limited to a nominal 400mA with a 4V drop on that range – crazy, huh?

By now, you should understand that burden voltage can be a real hidden disaster lurking in your meter. What is your meter rated at?

Accuracy

And the second problem we mentioned? That would be one of accuracy or lack of it. Most multimeters have a much poorer accuracy specification for current than for the DC voltage ranges or the 'Basic DC Accuracy' as it's called.

The Meterman 37XR, for example, is quite an accurate meter at ±0.1% (+5 counts) on DC volts and is sold and marketed as such. But its current accuracy is a not so impressive ±0.5% (+10 counts) on DC current and ±1.5% for the 10A range.

An even better example is the Fluke 27, with ±0.1% (+1 count) DC volts accuracy and ±0.75% (+2 counts) mA/µA DC current accuracy. Other multimeters are very similar, with a factor of five or more between the DC volts and DC current accuracy being quite typical.

This issue applies to the AC voltage vs AC current ranges as well. Some meters can actually have very poor AC current accuracy and/or reduced AC frequency response compared to their AC millivolt range.

Take the Fluke 27 again as an example. Its ACV accuracy is ±0.5% (+3 counts) to 2kHz, but the AC current range is considerably worse at ±1.5% (+2 counts) to 1kHz.

µCurrent adaptor

You guessed it, the project presented here presents a neat solution to these issues. The 'µCurrent' (pronounced 'micro current') is a simple yet accurate professional-grade precision amplified current adaptor for multimeters. It provides up to a 100-fold reduction in burden voltage for a given current range.

An additional feature is a nanoamp (nA) current range. This gives any cheap 3.5-digit multimeter the ability to resolve 0.1nA (100pA). On a 4.5-digit multimeter it will resolve 0.01nA (10pA). And this comes with an excellent accuracy of <0.2%.

In most cases, µCurrent is also able to improve your meter's current range accuracy by using your meter's more accurate mV DC voltage range to display the DC or AC current. (Yes, yes, we know that AC current is a tautology but what else can you call it?)

For AC, the frequency response extends up to 10kHz, although the circuit's THD (total harmonic distortion) increases substantially above 2kHz. This is still a very respectable

AC response range, surpassing that of many digital multimeters on current and voltage ranges.

Typical accuracy of the μCurrent itself is better than 0.2% on the μA and nA ranges, and 0.5% or better on the mA range. Unfortunately, it is not easy to obtain a 0.1% precision shunt resistor for the mA range, as the 10-milliohm value is too low.

The burden voltage of the µCurrent is a fixed 10µV/μA and 10μV/nA on the lower ranges. It varies on the mA range due to the switch resistance, but 70μV/mA is a nominal upper figure. These figures are unmatched by almost any meter on the market.

So, for example, at a full scale of say 1000μA, that's a maximum burden voltage of only 10mV. So measuring the current rail of a 1.2V logic supply with full-scale resolution would give you a worst case drop of around 0.8%, a fairly insignificant figure.

The output voltage in mV is directly proportional to the input current, so you can simply read the current value from your multimeter's mV DC range.

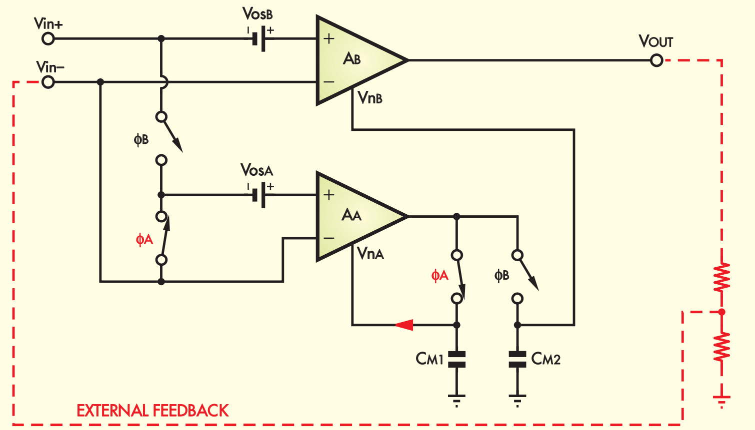
The μCurrent thus effectively eliminates burden voltage by making it insignificant in all but the most extreme applications.

How it works

A current adaptor is basically just a shunt resistor with an amplifier. But there are a few extra neat features to the μCurrent design to make it as professional and handy as possible, as we'll see. The full circuit is shown in Fig.1.

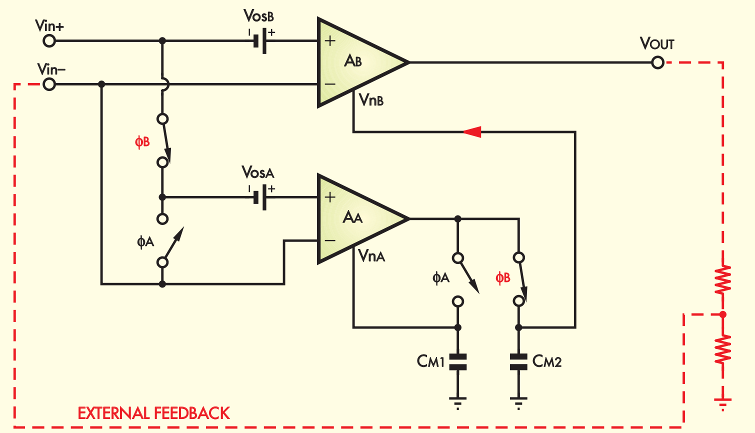
The heart of the design is IC1, a Maxim MAX4239. This is a special 'ultra-low offset/drift, low noise precision amplifier'. As the name suggests, it's a pretty high-spec device. The key figure in this application is its near-zero offset voltage. It doesn't just have a 'low offset' like many precision op amps; this one has almost no practical offset voltage at all. It is typically 0.1µV, with a maximum figure of 2.5μV over the entire temperature range.

This class of op amps is known as an 'auto-zero' (or 'chopper') amplifier. Maxim is a bit hush-hush on the actual internal workings of their particular device, saying only that 'these characteristics are achieved through a patented auto-zeroing technique that samples and cancels the input offset and noise of the amplifier. The pseudo-random clock frequency varies from 10kHz to 15kHz, reducing intermodulation distortion present in chopper-stabilised amplifiers'.



Auto-Zero Phase A: Null amplifier nulls its own offset

Fig.2(a): how a basic auto-zero amplifier works. In the first phase, the main amplifier (A_B) is offset with the voltage stored on capacitor C_{M2}. The nulling amplifier (A_A) measures its own offset voltage and stores it on capacitor C_{M1}.



Auto-Zero Phase B: Null amplifier nulls the main amplifier offset

Fig.2(b): in the second phase, the nulling amplifier (A_A) measures the input difference voltage on A_B and stores this value on capacitor C_{M2}, ready for the next cycle.

However, we can get a good idea of how a basic auto-zero amplifier works by referring to Fig.2.

An auto-zero amplifier is basically the combination of a normal op amp (A_B) with a 'nulling' op amp (A_A) that continually corrects for the DC offset voltage of the main amplifier. The device is driven by an internal clock that drives a two-phase offset process.

In the first phase, in Fig.2(a), the main amplifier (A_B) is offset with the voltage stored on capacitor C_{M2}. The nulling amplifier (A_A) measures its own offset voltage and stores it on capacitor C_{M1}.

In the second phase, in Fig.2(b), the nulling amplifier (A_A) measures the input difference voltage on A_B and stores this value on capacitor C_{M2}, ready for the next cycle. This process continually eliminates the offset voltage of the main amplifier.

A side benefit of this is that it also eliminates typical op amp 1/*f* noise, as the low frequency is treated as a slowly varying input offset voltage and hence gets cancelled out.

The pseudo-random clock used in the MAX4239 also helps to reduce the effects of intermodulation distortion as AC signals approach half the chopping frequency (10kHz to 15kHz).

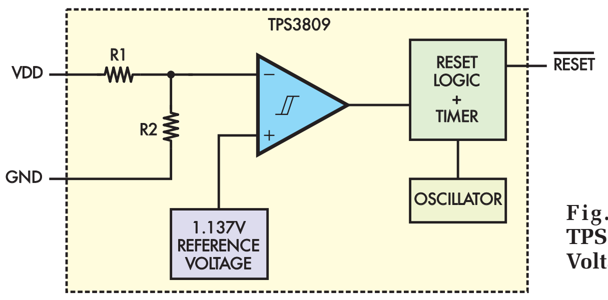


Fig.3: inside the TPS3809L30 Supply Voltage Supervisor.

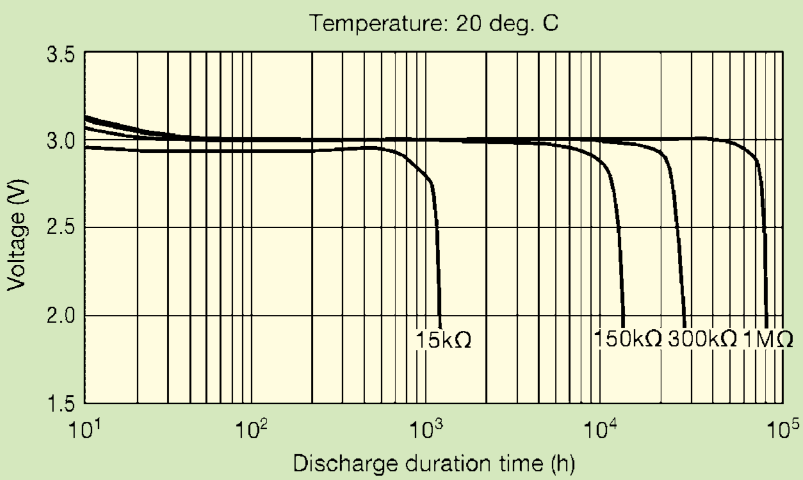


Fig.4: the discharge curves for the 3V lithium battery specified (CR2032), using a number of different loads.

This remarkable DC performance allows the µCurrent to have insignificant output offset error. As a result, it will display 0V output for a zero current input.

It is also quite a low power device, drawing around 600µA with a supply voltage specified down to 2.7V. This makes it ideal for operation from a single 3V lithium battery.

The MAX4239 also has a companion device, the MAX4238. The only difference is that the MAX4239 is a high bandwidth 'decompensated' version of the MAX4238. The MAX4239 requires a minimum gain of 10, which we have in this circuit, so it's better to use the higher bandwidth device.

If you want to use the MAX4238 then that is possible without any circuit changes, only the bandwidth and other AC performance measurements will differ.

A fixed gain of 100 is defined by precision resistors R5 and R3+R11. These are 0.1% resistors with negligible temperature drift.

The 100Ω resistor R9 at the output of IC1 ensures stability. This value will be low enough to ensure error-free operation with multimeters having greater than 100kΩ input impedance. If for some reason your meter is lower than this, than you'll have to lower the value of R9 appropriately.

Current ranges

There are three current ranges that are defined by the shunt resistor on each range, together with the gain of IC1.

The shunt resistor R2 (10kΩ 0.1%) is for the nA range, and is permanently connected across the input terminals. It gives a burden voltage of 10µV/nA (1nA × 10kΩ). The other shunt resistors R1 and R8 are disconnected in the nA range. R2 is permanently connected, ie, not switched, to ensure that the input is not left open-circuit.

Resistor R8 (10Ω 0.1%) is switched in parallel with R2 in the µA range by S1b, which gives a burden voltage of 10µV/µA (1µA × 10Ω). R2 contributes a small error of less than 0.1% in this case. It can be ignored.

Resistor R1 (10mΩ 0.5%) is switched in parallel with R2 in the mA range by S1b, which gives a (resistor) burden voltage of 10µV/mA (1mA × 10mΩ). Because R1 is such a low value, the solder joints and the copper tracks of the PC board can contribute large errors, so a special purpose-designed 'shunt' resistor is used. This is a 4-terminal device that includes the 10mΩ resistor and two 'sense' terminals connected directly across the resistor on the substrate. This eliminates any errors caused by solder joint or copper track resistance.

However, because the 10mΩ shunt resistor is such a small value compared with the resistance of the range switch, the switch itself will dominate the actual total burden voltage. The switch contact resistance is rated at 70mΩ maximum, so the actual burden voltage on the mA range will vary from unit to unit and will change with time, but can be taken as a nominal 70µV/mA.

The maximum current in the mA range is a nominal 300mA, as this is the contact rating of the switch. But in practice it can be higher than this.

You will notice that the virtual ground is connected to the sense side of R1. This means that the sense currents for R2 and R8 also flow through this terminal, but these currents are negligible, and so they have virtually no effect.

The switch contacts of S1a select which shunt resistor voltage gets fed through to op amp IC1.

Power supply

Any current adaptor must be able to handle both positive and negative inputs, so a dual-polarity power supply is required. In a battery-powered device, this can be achieved in one of three ways.

The first way is by using two or more series batteries to a middle '0V' tap. This method is convenient, but takes more space, plus there are more batteries to replace, and you can get uneven current drain from the batteries, thus making true low-battery detection more difficult.

The second way is by using a single battery supply and generating a negative supply using a switched capacitor inverter. This is convenient for low

Specifications

Three current ranges:
(1) ±0-300mA (70µV/mA burden voltage typical)
(2) ±0-1000µA (10µV/uA burden voltage)
(3) ±0-1000nA (10µV/nA burden voltage)

Output voltage units: 1mV/mA; 1mV/µA and 1mV/nA

Resolution (nA range): 100pA (3.5-digit meter), 10pA (4.5-digit meter)

Accuracy (typical): <0.2% on µA and nA ranges, <0.5% on mA range

Output offset voltage: negligible on 4.5-digit meter

Bandwidth: 2kHz nominal (±0.1dB)

Temperature drift: insignificant over normal ambient range

Noise: < –90dBV

THD: < –60dB

Battery: CR2032 lithium coin cell

Battery life: >200 hours (LED OFF); >50 hours (LED ON)

Connection: 4mm banana, screw terminal inputs, standard 19mm spacing

current applications, but it generates noise and requires filtering. Also, using a 3V lithium battery means a total power supply voltage from 5.4V to over 6V. But our MAX4239 can only handle a maximum of 5.5V supply voltage, so extra diodes would be required.

The third method involves a 'virtual ground' split supply circuit and this is the technique used in the µCurrent circuit. In effect, the two 100kΩ resistors comprise a voltage divider and this is buffered by op amp IC2, which is connected as a unity gain voltage follower to provide a low impedance output. However, the output impedance is increased by the series 100Ω resistor, which has been included to ensure output stability.

The output from the 100Ω resistor (R10) is now the 'virtual ground' reference for the rest of the circuit. This ensures that IC1 has a ±1.5V supply from the battery and the input current shunt resistors can now sense current in either direction.

IC2 is an LMV321 general-purpose, low-power, low-voltage op amp (essentially a low-voltage version of the venerable LM351). The total current drain for this portion of the circuit is about 145µA.

Low battery detection

To ensure that what you read on your multimeter is accurate, it is important to know if the battery voltage is low, and thus possibly affecting the measurement. IC3, a Texas Instruments TPS3809L30 Supply Voltage Supervisor, does this job accurately in a single chip. It contains a precision resistor divider, a voltage reference and an output circuit with timer (Fig.3).

If the input voltage on the V_{DD} pin drops below 2.64V, then the $\overline{\text{Reset}}$ output will go low. In our application, $\overline{\text{Reset}}$ will be high and thus the BATT LED will be on if the battery voltage is above 2.64V. Conveniently, this is about the 'end point' for a 3V lithium coin cell. The discharge diagram for the lithium battery, using a number of different loads, is shown in Fig.4.

By using the same type of 2-pole 3-position switch used for the current range selection, we are able to get a very handy 'battery check' mode between the ON and OFF modes, to switch in IC3 to light the LED. You can keep using the µCurrent in this mode with the LED ON if desired, but it does use more battery power.

The in-built timer will take about 0.2s to light the LED, so it's possible to move the power switch through the BATT CHECK mode and not have the LED light, if you are quick enough.

Output voltage range

The MAX4239 is capable of swinging its output fairly close to the supply rails. Given that the power supply will be at least ±1.35V for a working battery, this means that the output voltage can approach this figure within a few millivolts.

Normally though, the µCurrent will be used with your multimeter's mV range, which will be typically up to a maximum of 999.99mV for a 10000-count meter. So there is some headroom left if you want to push it higher for any reason.

Output units

The output units are scaled by the shunt resistors and gain of IC1 to be precisely 1mV per range unit. So the output will be 1mV per mA, 1mV per µA or 1mV per nA.

This makes it easy and logical to directly read on your multimeter's mV range. So, if you read 100mV on your

Parts List

1 µCurrent double-sided PC board, code 802, available from the *EPE PCB Service*, size 79mm × 50mm
1 UB5 plastic box, 83mm × 53mm × 28mm
1 CR2032 3V lithium cell
1 1060TR CR2032 SMD battery holder
2 miniature 3-position PC-mount slide switches, C&K JS203011AQN
1 4mm black banana jack
1 4mm red banana jack
1 4mm black binding post
1 4mm red binding post

Semiconductors
1 MAX4239ASA+ SO8 op amp (IC1)
1 LMV321AS5X SOT23-5 op amp (IC2)
1 TPS3809L30DBVR SOT23 voltage monitor (IC3)
1 LTST-C230GKT 1206 reverse green LED

Capacitors
3 100nF 0805 (SMD) Capacitors

Resistors (surface-mount)
2 100kΩ 1% 0805
1 75kΩ 0.1% 0805
1 24kΩ 0.1% 0805
1 10kΩ 0.1% 0805
1 1kΩ 0.1% 0805
1 470Ω 1% 0805
3 100Ω 1% 0805
1 10Ω 0.1% 0805
1 LVK12R010DER 10mΩ 0.5% 1206 (current sense)

Where To Buy
This design is copyright to the author. Both kits and fully-built units are available from him at:
www.eevblog.com/shop

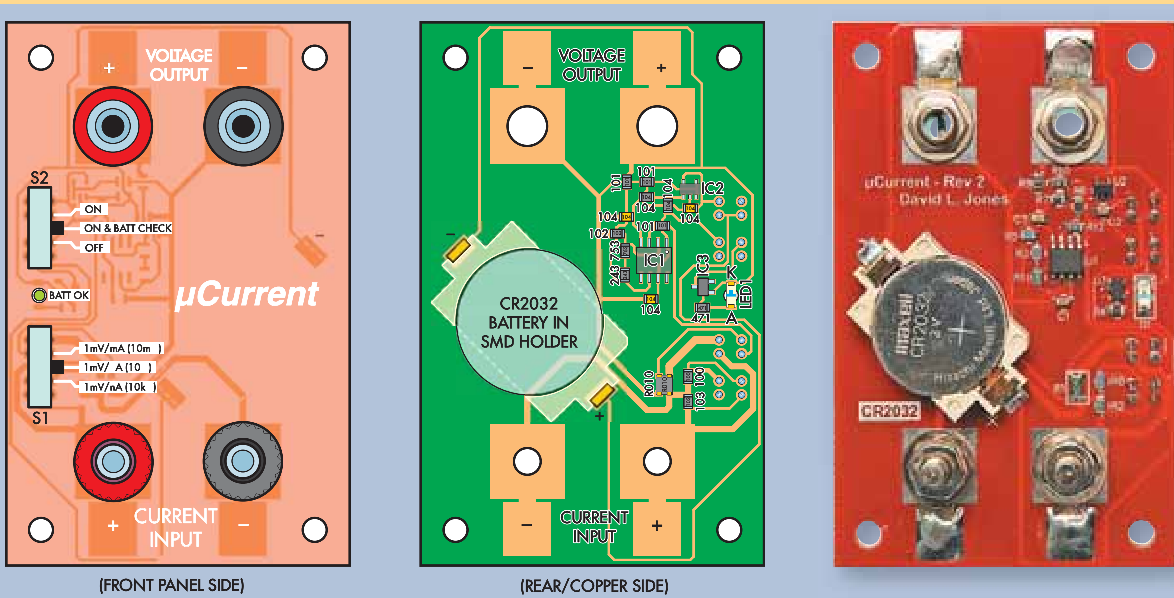


Fig.5: install the parts on the PC board as shown here. You will need a soldering iron with a small chisel-point tip to solder the SMD devices to the board, along with a pair of fine-pointed tweezers and some fine solder.

The PC board, together with a piece of lettered coloured card, forms the front panel.

meter, that equates to 100mA, 100μA, or 100nA, depending on the range you have selected.

AC performance

The AC performance is shown in the accompanying screen shots (Fig.6 and Fig.7) as measured with an Audio Precision analyser with a 1V output level on the μA range. There is little performance difference between the ranges.

The nominal bandwidth is 2kHz, as the THD starts to increase exponentially after this. This figure is quite sufficient, as most meters have a response of 1kHz on AC current ranges.

Overloads

Fuses have been omitted from the design to ensure as low a total burden voltage as possible. **Therefore, you must be careful to ensure that the input is not connected directly across a supply voltage capable of providing a current that exceeds the selected range. Failure to take care here can result in a blown shunt resistor.**

Connectors

The connectors are standard 4mm ‘banana’ plugs, with standard 19mm spacing. This allows the use of various types of adaptors if required. The screw-terminal type connectors are used for the current input, which is convenient for connecting to existing wiring without test leads. The top screw part can be completely removed to enable some short ‘shrouded’ banana plug test leads to fit.

Construction

Apart from the connectors and miniature slide switches, the entire design uses surface-mount components (SMDs). This is in order to give a professional look and to reduce cost and size by using a standard UB5-size box. The double-sided, surface-mount, PC board is used as the lid and front panel of the box. This board is available from the *EPE PCB Service*, code 802. Our board does NOT have plated-through holes. The shield plane on the top layer is connected to V_{GND}. You can, if you wish, cover the top layer with a lettered card.

All the SMDs are relatively large 0805, SO and SOT packages, so soldering is pretty easy using a basic iron. Refer to the July 2010 issue of *EPE* for a detailed article on how to solder surface-mount components, if you are new to this.

There are a few things that make SMD hand-soldering much easier: a small chisel point tip (not conical), fine multicore solder (0.56mm or better) and a pair of fine-pointed tweezers.

Start with the three IC packages, making sure each one is mounted with the correct polarity. Follow these with the resistors and capacitors, taking special care not to damage the precision resistors with excess heat.

Applying a small amount of solder to one pad first makes it easy to ‘reflow’ the component into place while you solder the other end.

Next, solder in the LED. This is a special ‘bottom emitter’ LED which is effectively soldered in upside down, with the light coming through a hole in the board. Be sure to check the polarity – see Fig.5.

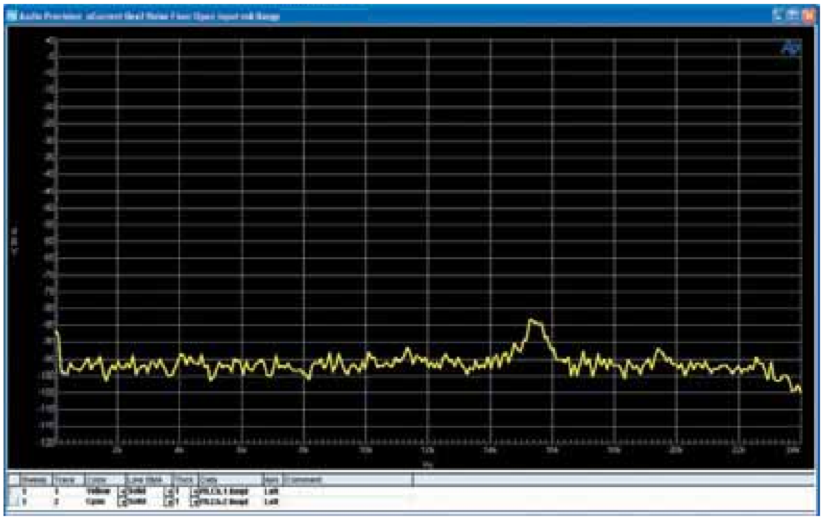


Fig.6: this Audio Precision spectrum plot shows the residual noise of the μCurrent Adaptor circuit.

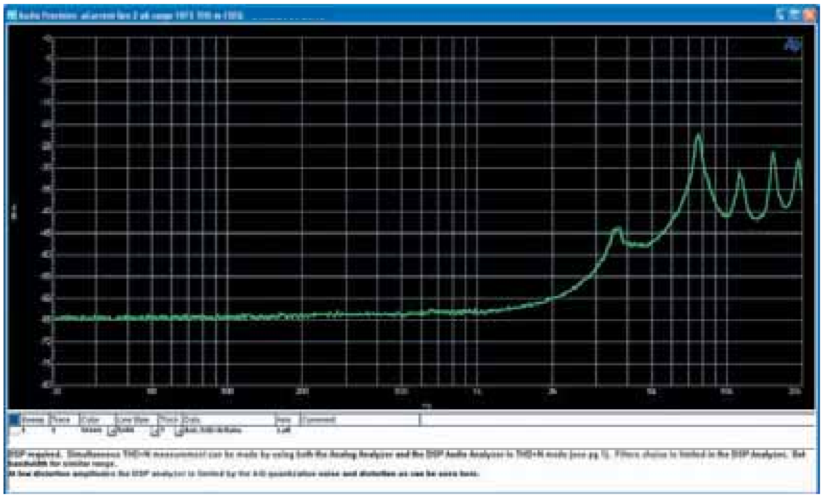


Fig.7: although largely of academic interest, this Audio Precision plot shows the THD *vs* frequency of the μCurrent Adaptor at a signal level of 1V.

Next, solder the battery holder into place, ensuring the correct polarity. Apply the iron and then solder to the topside of the flat pin instead of the pad for this part. The solder should then reflow easily to the pad underneath.

Now turn the board over and install the two miniature slide switches, again ensuring correct orientation. If you have the vertical switches, then the side with the metal indent should face to the outside edge of the board. Side mount switches should have the switch lever towards the middle of the board. Ensure that the switches are flush with the board and straight, then tack one pin down first. Check that everything is OK before soldering the rest.

Finally, install the banana connectors. Unscrew them completely first, removing all nuts, washers and solder tags. Install them on the topside with just the plastic spacers touching the topside of the PC board. Next, put the solder tag on the bottom side and solder it only to the smaller adjacent solder pad, then place the washer and screws on top and tighten. Feel free to add a thread-locker and/or glue if desired.

Testing

Testing is fairly straightforward. You will need a power supply, some suitable resistors and your multimeter.

Insert the battery and switch to BATT CHECK mode. The LED should light within 0.2s. Switch to ON mode and the LED should turn off.

Measure the DC voltage from the negative output connector (V_{GND}) to first one then the other side of the battery in order to check the split supply system. You should get approximately ±1.5V and both values should match closely.

Next, connect the Voltage Output terminal to your multimeter and set the multimeter to its mV DC range. With nothing connected, you should get a reading of zero on all three current ranges.

The next step is to select a resistor for each range to give you a decent current level, eg, around half the meter's full scale. For example, for a 5V supply, use a 47Ω 1W resistor (106mA), a 47kΩ resistor (106μA) and five 10MΩ resistors in series (100nA).

That done, connect the test resistor in series with the supply and the Current Input terminals. Ensure that you have the correct range selected before switching on your supply voltage – you don't want to blow any shunt resistors!

Your meter should read approximately 106mV (mA), 106mV (μA) and 100mV (nA) for the values mentioned. You can double-check your values by measuring the actual resistor values and supply voltage and calculating the current if desired.

If these currents match, then your µCurrent is ready for operation, as the calibration is inherent within the precision 0.1% components used. The output value should not differ between BATT CHECK and ON modes.

It might be handy to check the battery current also. It should be around 0.7mA with the LED off, and around 3mA with the LED on. Don't forget to switch off when you are finished measuring.

The last step simply involves screwing the PC board and card (if used) onto the box. With typical infrequent use, the battery should last many years.

That's all there is to it. You now have a precision current measurement tool ready for those more demanding applications. We hope this article has got you thinking about the impact burden voltage can potentially have on current measurements. ***EPE***

Blinded by the light

TechnoTalk

Mark Nelson

If nice, straightforward LEDs are the future of lighting, why are we still wasting time lighting our homes and offices with anaemic compact fluorescents? Mark takes a look at the latest developments in lamps that make sense.

IT's a perfectly fair question: why can't we have LED-based lamp bulbs now? Everyone knows they are more effective, efficient, economical and environmentally-friendly than what most shopkeepers want to sell us today. Well, it may surprise you that you can.

When you're next in front of your computer, log onto the Radiospares website (**http://uk.rsonline.com/**) and find item 310-6757. It's an LED lamp with a standard bayonet cap fitting (also available with an Edison screw base). It uses a cluster of 20 white LEDs and consumes just 2.5W, a fraction of the power its incandescent equivalent guzzles. The only snag is the price, £59.88 + VAT for a single lamp.

There's the rub: these lamps are relatively new and the design looks a bit clunky, meaning they don't sell in vast numbers. So they're not as cheap as chips – yet.

The future's bright

Analysts agree that the day when LED dominates the general lighting market is not far off. According to Digitimes Research, a Taiwan-based consulting firm tracking technology trends, 2011 will be the year that LED bulbs will emerge as mainstream.

F H Lin, a market analyst and project manager of the consulting firm states: 'Consumption of LED bulbs will be driven by subsidies encouraging energy-saving products in North America, the European Union, Japan and South Korea, as well as a rising willingness to buy such lighting at the retail level.' She adds that major economies are designating LED lighting as critical elements of their energy policy to meet the global 'eco' trend. The market value of LED lighting for 2011 is likely to total \$15.4 billion worldwide, or 10.6 per cent of the total lighting market.

That's good news if the new bulbs can match compact fluorescents for price, and don't look like a lab prototype. That last point is not lost on American lamp manufacturer Cree, which four months ago demonstrated the brightest, most-efficient, LED-based design that can meet 'Energy Star' performance requirements for a 60W standard LED replacement bulb. 'This is a significant milestone for the industry,' said Chuck Swoboda, Cree chairman and chief executive officer. 'In the race to commercialise low-cost, energy-efficient LED bulbs, the industry has forgotten that LED lighting is supposed to look as good as the technology it is replacing. This is the first no-compromise replacement for a 60W incandescent bulb.'

He has a point, because concentrations of LEDs create significant heat that needs to be dissipated using vaned heatsinks. This is a function of the inefficiency of the semiconductor processes that generate light, and it is essential to remove this heat through efficient thermal management to avoid altering the desirable characteristics of the LEDs. Fortunately, Cree has styled its lamp to minimise the effect of the heatsink and it looks rather like an incandescent mushroom bulb with some discreet fins on the 'stalk' of the mushroom. You can see for yourself at: **www.truewhitelight.com**

Not many know this

It's not always realised that the electrical efficiency (optical power out, divided by electrical power in) of LED packages is typically in the region of five to 40 per cent, meaning that somewhere between 60 and 95 per cent of the input power is lost as heat. Fortunately, the input power used is far less than for equivalent incandescent bulbs.

In a nutshell, a 100W incandescent bulb produces around 12 per cent heat, 83 per cent infrared, and just five per cent visible light. By way of comparison, a typical LED could produce 15 per cent visible light and 85 per cent heat (source: *LEDs Magazine*).

One manufacturer that has already discovered this to its cost is Eco-Story, of Portland, Maine. In January, it issued a recall notice for the 42,000 LED low-voltage downlighter LED bulbs it had sold following concerns over overheating. This was required after a customer reported that two lamps had melted in their fixtures.

Although this was the sole occurrence reported and nobody was injured, the company acknowledges there is a possible fire risk. The replacement LED lamp has a dual fuse system to prevent any fire hazard.

I can't wait!

So what if you want a replacement LED bulb now? The only company I can find that manufactures direct replacements is Osram, with its Parathom Classic range. These have the traditional shape and come in a number of power ratings. The retail price ranges from £9 to £14, with reductions for quantity (see: **www.stagelamps.co.uk**). Unfortunately, these are low power and if you want the equivalent of a 60W incandescent you'll have to wait until the end of the year.

At the press launch of their product, Cree's spokeswoman admitted: 'This is a demonstration, not an introduction. It hasn't yet been decided how or if this will be brought to market. Pricing hasn't been established yet, but it was designed to be low cost.' The same applies to other firms who have announced LED replacements for the traditional bulb. Informed sources expect the launch price to be just under US\$50.

Report revisited

Please turn away now if you're bored of reading about the new wonder material, graphene. Still with us? Good.

Researchers at Rice University (Houston, Texas) have discovered how to make perfect sheets of graphene, the one-atom-thick form of carbon, from plain table sugar and other carbon-based materials. What's more, they do this in a single-step process at temperatures low enough to make graphene easy to manufacture.

As always, the figures are relative; the temperatures under discussion are as 'low' as 800°C (1,472°F). 'As hot as that may seem, the difference between running a furnace at 800 and 1,000°C is significant,' declares Rice chemist James Tour. He acknowledges that the hard work was done by Zhengzong Sun, a fourth-year graduate student.

Sun started with a thin film of poly methyl methacrylate (Perspex), spun onto a copper substrate that acted as a catalyst. Under heat and low pressure, flowing hydrogen and argon gas over the PMMA for 10 minutes reduced it to pure carbon and turned the film into a single layer of graphene.

'Then it got more interesting', Sun said. He turned to other carbon sources, including a fine powder of table sugar. After he put 10mg of sugar on a square-centimetre sheet of copper foil and subjected it to the same reactor conditions as the Perspex, it was quickly transformed into single-layer graphene. His supervisor summed up, 'Each day, the growth of graphene on silicon is approaching industrial-level readiness.'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Digital Audio Oscillator

Design By DARIAN LOVETT
Words by MAURO GRASSI

Do you need to test audio equipment, including amplifiers and speakers, in the field and in the workshop? If so, you could use this compact and inexpensive digital audio oscillator. It can produce sine, square, triangle and sawtooth waveforms in the frequency range from 10Hz to 30kHz, and features three output ranges: 20mV, 200mV and 1V.

THIS compact handheld digital audio oscillator will allow you to quickly test wiring and to diagnose faults in audio systems. It is ideal for testing amplifier and speaker set-ups, and is portable and easy to use.

To use it, you simply select one of four waveforms – sine, square, triangle or sawtooth – and set it to a frequency between 10Hz and 30kHz. The digitally synthesised waveform is then available at the two RCA phono outputs. These two outputs are in parallel and are doubled-up simply for your convenience. It means you can test a stereo amplifier and speaker set simultaneously.

Turning to the front panel, there is a four-position slide switch that selects one of three levels for the output signal: 20mV, 200mV and 1V. Each selected level can be continuously varied down to zero with the 'Level' control.

There are also three pushbuttons on the front panel. The two on the right increase or decrease the frequency of the output waveform. The output frequency and the waveform type are shown on a blue backlit LCD screen.

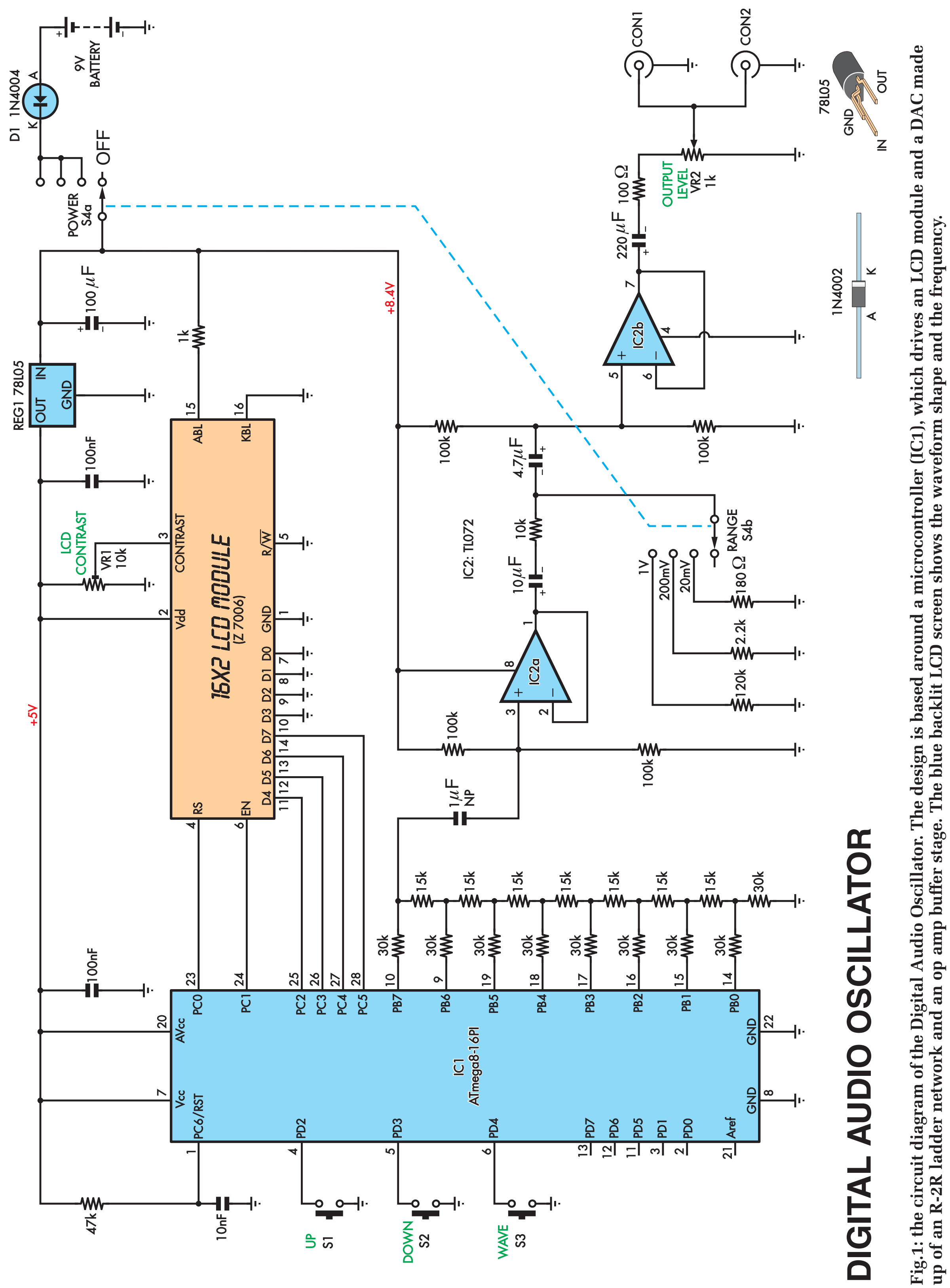
Pressing the 'Wave' button on the left, while at the same time pressing the 'Down' button on the right, lets you scroll through the four different waveform types: sine, square, triangle and sawtooth. It's that easy!

Circuit details

Fig.1 shows the full circuit diagram. It uses an Atmel microcontroller (IC1) to implement most of the features.

The unit is powered from a single 9V battery. As shown, the +9V rail is fed via reverse-polarity protection diode D1 to one pole of a 2-pole 4-position slide switch, S4a. In three of the four positions, the switch feeds the resulting +8.4V rail on D1's cathode (K) to voltage regulator REG1. In turn, REG1 outputs a +5V rail, which is used to power the microcontroller, while the +8.4V rail from diode D1 is used to power op amps IC2a and IC2b.

In operation, IC1 monitors pushbutton switches S1 to S3. These switches are respectively connected to digital inputs PD2 to PD4, which have weak internal pull-ups. When a switch is pressed, the relevant input is pulled low and this is detected by IC1 and processed by the internal



DIGITAL AUDIO OSCILLATOR

Fig.1: the circuit diagram of the Digital Audio Oscillator. The design is based around a microcontroller (IC1), which drives an LCD module and a DAC made up of an R-2R ladder network and an op amp buffer stage. The blue backlit LCD screen shows the waveform shape and the frequency.

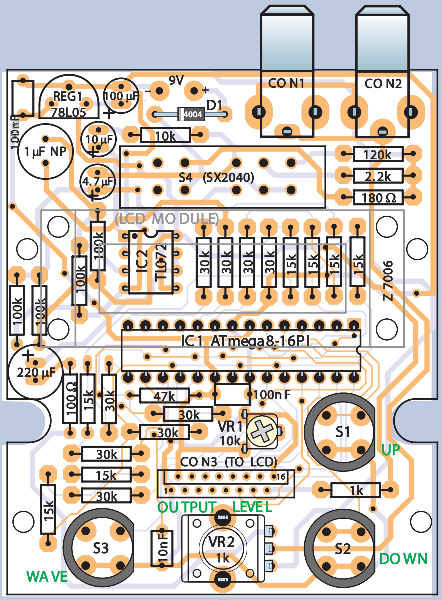


Fig.2: follow this parts layout to build the Digital Audio Oscillator. Be sure to install the electrolytic capacitors and semiconductors with the correct polarity and note the orientation of switches S1-S3.

software. This sets the waveshape (sine, square, triangle or sawtooth) and the frequency, and displays the result on a 16×2 LCD module.

As shown, the microcontroller drives the 16×2 LCD module using its PC0 to PC5 digital output lines. Trimpot VR1 sets the display contrast, while power for the LCD is derived directly from the +5V rail. The 47kΩ resistor and 10nF capacitor on pin 1 of IC1 reset the microcontroller at switch on.

D-to-A converter

As well as the LCD module, microcontroller IC1 also drives a digital-to-analogue (D/A) converter via its PB0 to PB7 digital output lines. This D/A converter is made up of an R-2R ladder network and has 8-bit resolution.

In this case, R = 15kΩ and there are seven 15kΩ resistors and nine 30kΩ resistors in the ladder network. The output of any N-stage R-2R network is given by:

$$V_{OUT} = D_N \times V/2^N$$

where V_{OUT} is the output voltage, D_N is the digital value as an N-bit number, and V is the supply rail.

In our case, N = 8 (so $2^N = 256$), V = 5 and D_N is given by bits PB7 (MSB) to PB0 (LSB) which are digital outputs of IC1. The accuracy of such a DAC is constrained by the accuracy of the resistors. Note that in this case, 1% resistors are used throughout.

The output of the DAC is AC-coupled to op amp stage IC2a (TL072) via a 1µF non-polarised (NP) capacitor. This op amp stage has its non-inverting input (pin 3) biased to half-supply by two 100kΩ resistors, and is wired as a unity-gain buffer stage.

Attenuator

IC2a's output appears at pin 1 and is AC-coupled to an attenuator stage (switch S4b and associated parts) via a 10µF capacitor and a 10kΩ resistor. As shown, the signal is fed to the wiper of switch S4b, which selects the output level range.

In operation, S4b selects a divider consisting of the 10kΩ resistor and either a 120kΩ, 2.2kΩ or 180Ω resistor to GND, in parallel with the two 100kΩ bias resistors for IC2b. These selections correspond to the 1V, 200mV and 20mV amplitude ranges, respectively.

Selecting the 120kΩ resistor provides the 1V range, while selecting the 2.2kΩ resistor provides the 200mV range. The 180Ω resistor gives the 20mV range.

Output buffer

The output of the divider is AC-coupled to op amp output stage IC2b, this time via a 4.7µF capacitor. This op amp is also biased to half-supply using two 100kΩ resistors and also operates as a unity-gain buffer stage. Its output signal at pin 7 is fed via a 220µF capacitor and a series 100Ω resistor to potentiometer VR2, which sets the output level.

This side-on view shows how the LCD module is secured to the PC board using nylon spacers and screws.

The resulting signal at VR2's wiper is then fed to output sockets CON1 and CON2, which are connected in parallel.

Construction

The Digital Audio Oscillator is built on a double-sided PC board measuring 76mm × 62mm. Fig.2 shows the parts layout. This board is available from the *EPE PCB Service*, code 803. Our board does NOT have plated through holes. The software files will be available for free download via the *EPE* Library site at: **www.epemag.com**.

Begin construction by carefully inspecting the PC board for hairline cracks and for shorts between adjacent copper tracks. Once you have inspected the board, start the assembly by installing the resistors. Table 1 shows the resistor colour codes, but it's also a good idea to check them using a DMM as some colours can be difficult to distinguish. The diode can then be installed, taking care to orientate it exactly as shown on the parts layout diagram.

Voltage regulator REG1 in the TO-92 package can be soldered in next. It can only go in one way! Don't force the body down too close to the PC board or you may damage its connecting leads. It should ideally sit about 7mm off the board.

The non-polarised capacitors are installed next, followed by the polarised electrolytic capacitors. Make sure the latter are orientated correctly. Note also that the electrolytic capacitors *must* all be installed so that they sit flush with the PC board, to ensure they don't later foul the lid of the case.

A 28-pin IC socket is used for the microcontroller and this can be installed now. Be sure to orientate it with its notched end to the right, as indicated on Fig.2. Leave IC1 out for the time being – its plugged in later on, after some basic checks of the supply rail have been performed.

The PC board is secured inside the case using metal screws that go into integral mounting posts. Note that the battery leads are run under the PC board and into the battery compartment via a slot in the back wall.

IC2 (TL072) is next on the list. It's directly soldered to the PC board and goes in with its notched end towards switch S4. Be sure not to apply too much heat at any one time to its pins, as this could damage it.

The LCD connector (CON3) can now be soldered in, followed by potentiometer VR1, the two phono sockets (CON1 and CON2), switch (S4) and trimpot VR1. Follow these with the three pushbutton switches (S1 to S3) making sure that they are orientated correctly. Note that each has a straight edge and this must go to the right, as shown on the component overlay.

The last thing to do is to solder in the battery clip lead. The red lead goes to the +9V PC pad, while the black lead goes to the negative (–) pad. These pads are located at the top of the PC board, immediately to the left of the phono sockets.

That completes the PC board assembly, apart from plugging in IC1. As mentioned earlier, that's done only after making a few basic checks. Note also that the LCD module is not attached at this stage.

Initial tests

To test the assembly, first connect a 9V alkaline battery to the battery clip, then switch on and use a DMM to check the

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	120kΩ	brown red yellow brown	brown red black orange brown
❑	4	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	9	30kΩ	orange black orange brown	orange black black red brown
❑	7	15kΩ	brown green orange brown	brown green black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	2.2kΩ	red red red brown	red red black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	180Ω	brown grey brown brown	brown grey black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown

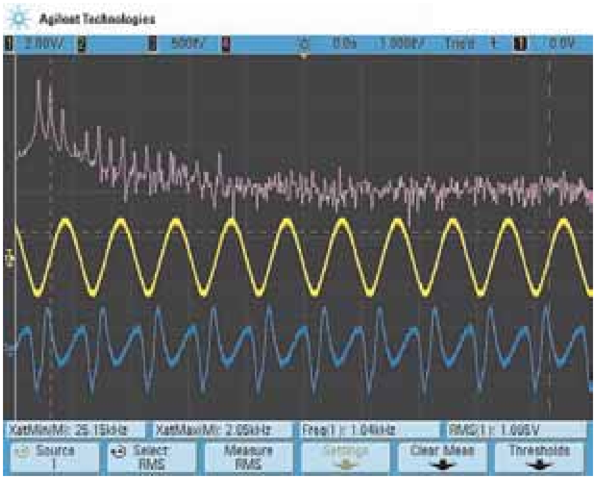


Fig.3: this oscilloscope screen grab shows a 1kHz sinewave (yellow trace), as captured at the output. The distortion waveform for THD+N (blue trace) can also be seen, as well as the FFT (Fast Fourier Transform) of the distortion. Note that the highest distortion peak is at the lower harmonics.

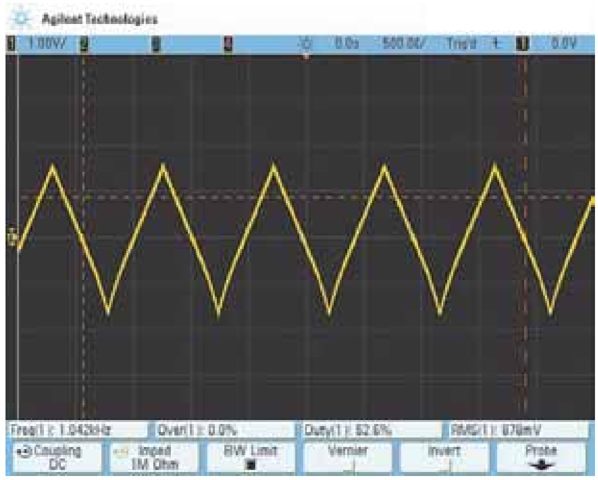


Fig.4: an oscilloscope screen grab of a triangular wave at around 1kHz. This shows that the waveform is very close to linear on the rising and falling slopes although there is some slight drooping discernible at the waveform troughs.

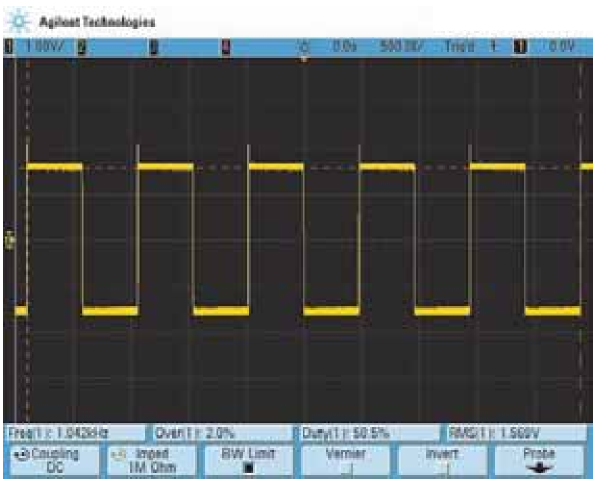


Fig.5: this shot shows the square wave output from the unit at around 1kHz. There is a 2% overshoot on the rising edge of the waveform, but little droop. Droop will only be apparent at low frequencies in the tens of hertz.

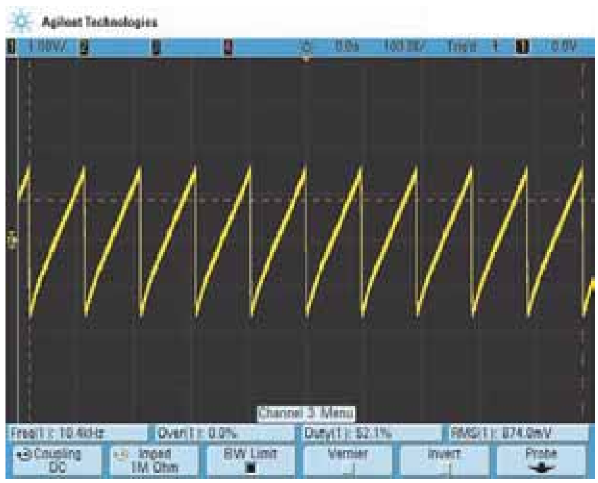


Fig.6: a sawtooth waveform at a nominal 10kHz. As shown, the actual frequency is 10.4kHz and the RMS value is also indicated. Note: this screen grab was obtained with the unit at full level on the 1V range.

Specifications

Frequency ranges: 10-200Hz in 10Hz steps; 200Hz-1kHz in 100Hz steps and 1-30kHz in 500Hz steps

Amplitude ranges: 0-20mV, 0-200mV and 0-1V RMS (output amplitude adjustable within the selected range)

Waveforms: sine, square, triangle and sawtooth

Frequency accuracy: ±4%

Total Harmonic Distortion + Noise: approximately 3%

Output connectors: 2 x RCA parallel mono outputs

Power supply: 9V alkaline battery

Current drain: 25mA

voltage between the OUT terminal of REG1 and the body of either phono socket. You should measure close to 5V and this voltage should also be present on pin 7 of IC1's socket.

If this voltage is correct, you can jump to the final installation section. If not, you should disconnect power immediately and perform a few checks:

1) Are you using a fresh 9V battery?

2) Is there 7V to 8.4V at the cathode of diode D1? If there isn't, then you may have D1 in the wrong way around.

3) If the voltage is still incorrect, double-check the PC board assembly.

Performance

WE checked the Digital Audio Oscillator on an Audio Precision Test set and the results are shown in Fig.7. Keep in mind, though, that it is not intended as a high-precision instrument.

For the sinewave output, we measured the THD+N (total harmonic distortion + noise) over the frequency range with four different bandpass filters – see Fig.7. The typical THD+N figure was around 3%, which is higher than most amplifier and speaker sets.

While this is not enough to worry about, it means you cannot use this oscillator in precision applications, where low distortion is paramount. It's quite good enough, however, for most troubleshooting tasks.

Fig.3 to Fig.6 on the facing page show screen grabs of the four different waveforms that can be selected. The frequency accuracy is within ±4% across the whole range, from 10Hz to 30kHz.

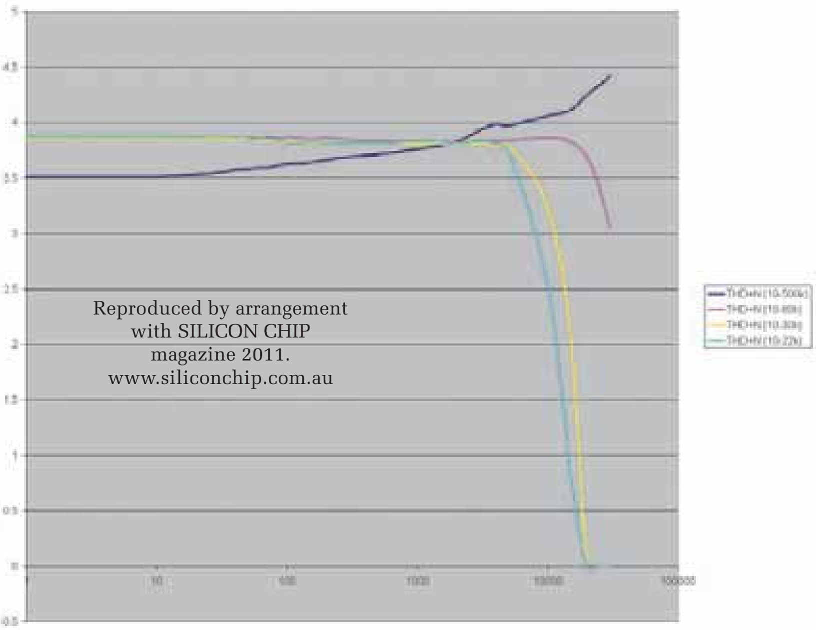


Fig.7: the sinewave THD+N vs Frequency for four different filter combinations. The filters range from <10Hz – >500kHz), <10Hz – 22kHz , <10Hz – 30kHz and <10Hz – 80kHz. The distortion is less with a more restrictive filter.

In particular, check for incorrect component orientation and for incorrectly placed parts. Check also for dry solder joints on the underside of the board.

Assuming that REG1's output is correct, switch off and plug IC1 into its socket (notched end to the right). The LCD module can also be installed.

To do this, mount the LCD module in position on the PC board using four M3 × 9mm nylon spacers and eight M3 × 6mm nylon screws. The module's flexi connector is then plugged into CON3 on the PC board.

The PC board can now be mounted inside the case and secured using four Phillips-head 10mm screws, supplied with the kit. When doing this, make sure that the two battery-clip wires pass underneath the PC board and into the battery compartment – see photo. The top of the case can then be fitted into position and secured using two Phillips-head 18mm screws.

Your Digital Audio Oscillator is now complete and ready for use. You can check that it is working properly by monitoring its output with a scope, or failing that, feeding its output into an audio amplifier system. ***EPE***

Parts List

- 1 double-sided PC board, code 803, available from the *EPE PCB Service*, 76mm × 62mm
- 1 plastic case, 79mm × 117mm × 24mm, Altronics H8971
- 1 16x2 LCD with blue backlight, Altronics Z7006
- 2 PC-mount RCA phono sockets
- 1 28-pin 0.3-inch machined IC socket
- 1 16-way PC-mount FFC/FPC connector, Altronics P4516
- 1 10kΩ 5mm trimpot, horiz. (VR1)
- 1 1kΩ log pot (9mm PC-mount), Altronics R2480B (VR2)
- 3 PC-mount pushbutton switches, (S1 to S3)
- 1 2-pole 4-position PC-mount slide switch, (S4)
- 4 M3 × 9mm nylon spacers
- 8 M3 × 6mm nylon screws
- 1 9V battery snap connector

Semiconductors

- 1 programmed Atmel ATmega8-16PI microcontroller (IC1)
- 1 TL072 dual op amp (IC2)
- 1 78L05 regulator (REG1)
- 1 1N4004 silicon diode (D1)

Capacitors

- 1 220µF radial elect, 16V
- 1 100µF radial elect, 16V
- 1 10µF radial elect, 16V
- 1 4.7µF radial elect, 16V
- 1 1µF 16V NP
- 2 100nF MKT polyester
- 1 10nF MKT polyester

Resistors (1%, 0.25W)

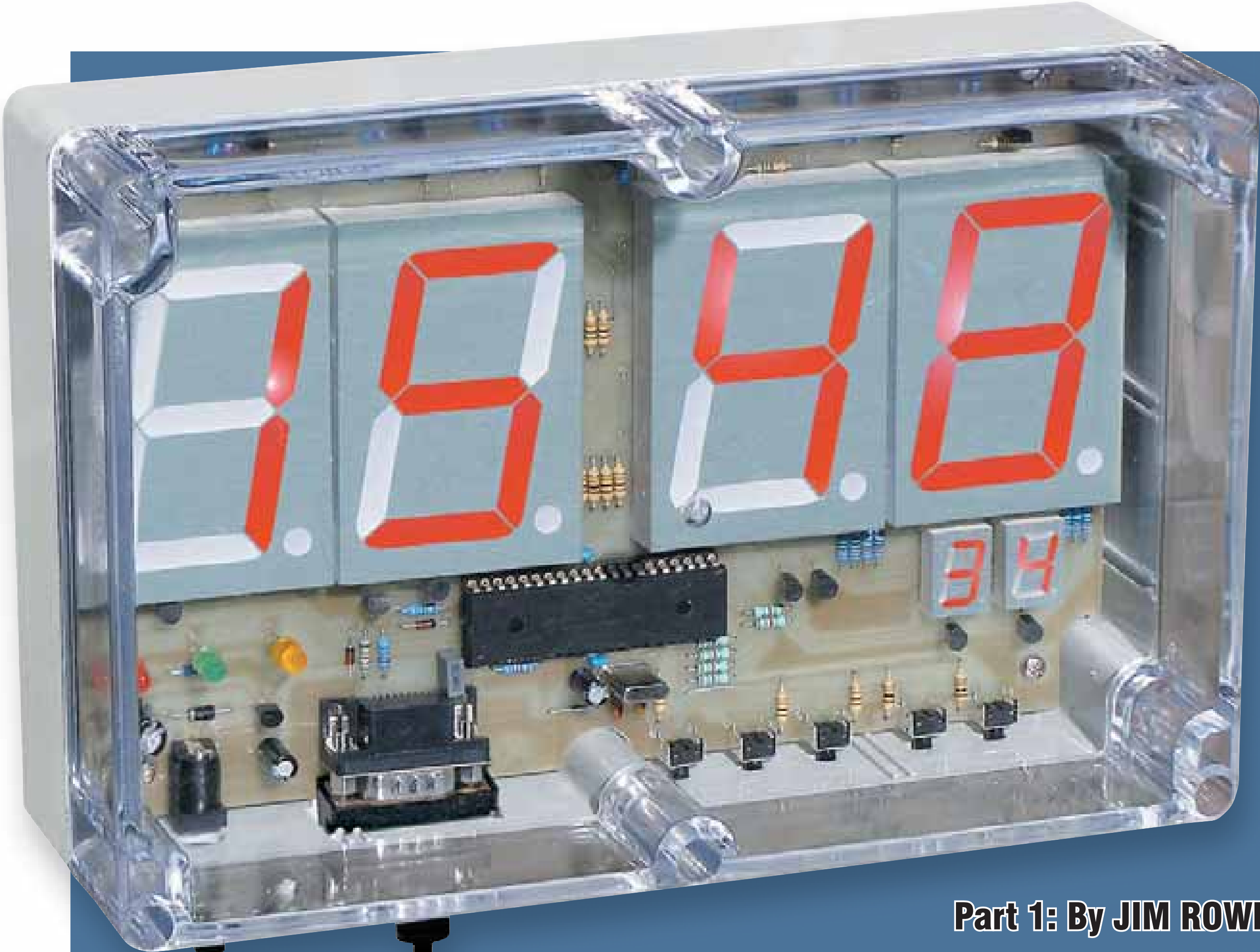
1 120kΩ	1 10kΩ
4 100kΩ	1 2.2kΩ
1 47kΩ	1 1kΩ
9 30kΩ	1 180Ω
7 15kΩ	1 100Ω

Where To Buy a Kit

This Digital Audio Oscillator was designed by Altronics, who own the design copyright. A complete kit of parts is available from Altronics for AU$89 (Cat. K2543) – check with Altronics for UK p&p.

The kit includes the PC board, the machined case and all specified components (including a pre-programmed microcontroller) but does not include a battery.

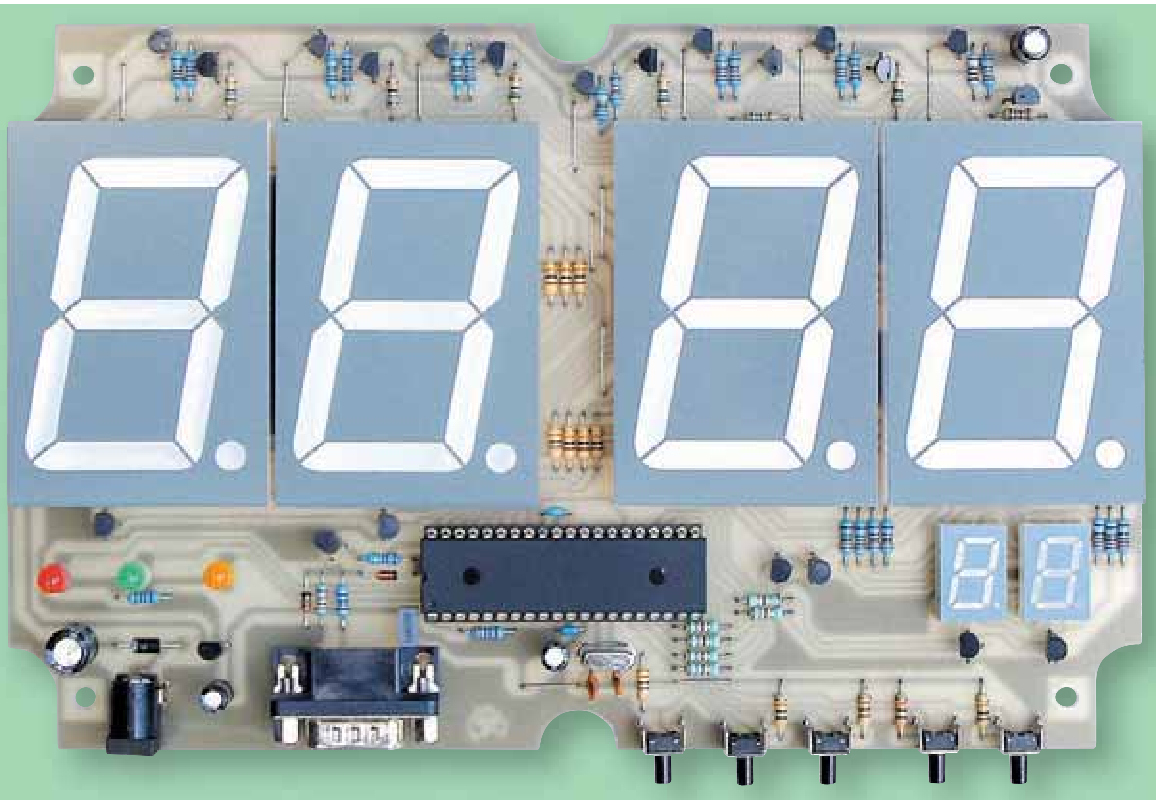
The kit is available at:
www.altronics.com.au



Part 1: By JIM ROWE

Build A 6-Digit GPS Clock

Looking for a digital clock that's always dead accurate? This one derives its time signals from the GPS (Global Positioning Satellite) system, so it never needs setting or adjusting. It features big, bright 58mm-high digits for the hours and minutes, plus smaller digits to indicate the seconds.



The main board uses 58mm-high 7-segment displays for the hours and minutes readouts, plus smaller 13mm-high digits to indicate the seconds. The GPS time signals are derived either from a small add-on module, to be described next month, or from the GPS-Based Frequency Reference (see text).

IN THE March 2011 issue, we featured a GPS-controlled analogue clock that's proving very popular. Strictly speaking though, this wasn't a GPS clock but a 'GPS-corrected' clock.

Basically, an external module carrying a PIC microprocessor and an EM-408 GPS module was used to replace the clock's own crystal oscillator drive. The PIC provides the timing signals for the clock and the GPS module is then used to re-synchronise the clock once every 44 hours.

By contrast, this digital clock is permanently locked to the GPS time signals and always displays the correct time. It can display UTC time (universal time coordinated), local standard time or local daylight saving time, all at the touch of a button.

The digital clock display described here can derive its GPS time signals from the *GPS-Based Frequency Reference* described in the April-May 2009 issues of *EPE*. However, you don't have to go to the expense of building the frequency reference. Instead, you can use the above-mentioned EM-408 GPS module on a small PC board, which can be housed in the same case as the display board to form a self-contained clock. This will be described in Part 2 next month.

GPS Frequency Reference

The GPS-Based Frequency Reference mentioned earlier already displays UTC time on its small LCD readout. In order to get your local time, you have to mentally add (or subtract) the appropriate offset for your particular time zone and also add another hour if your region or state is currently observing daylight saving.

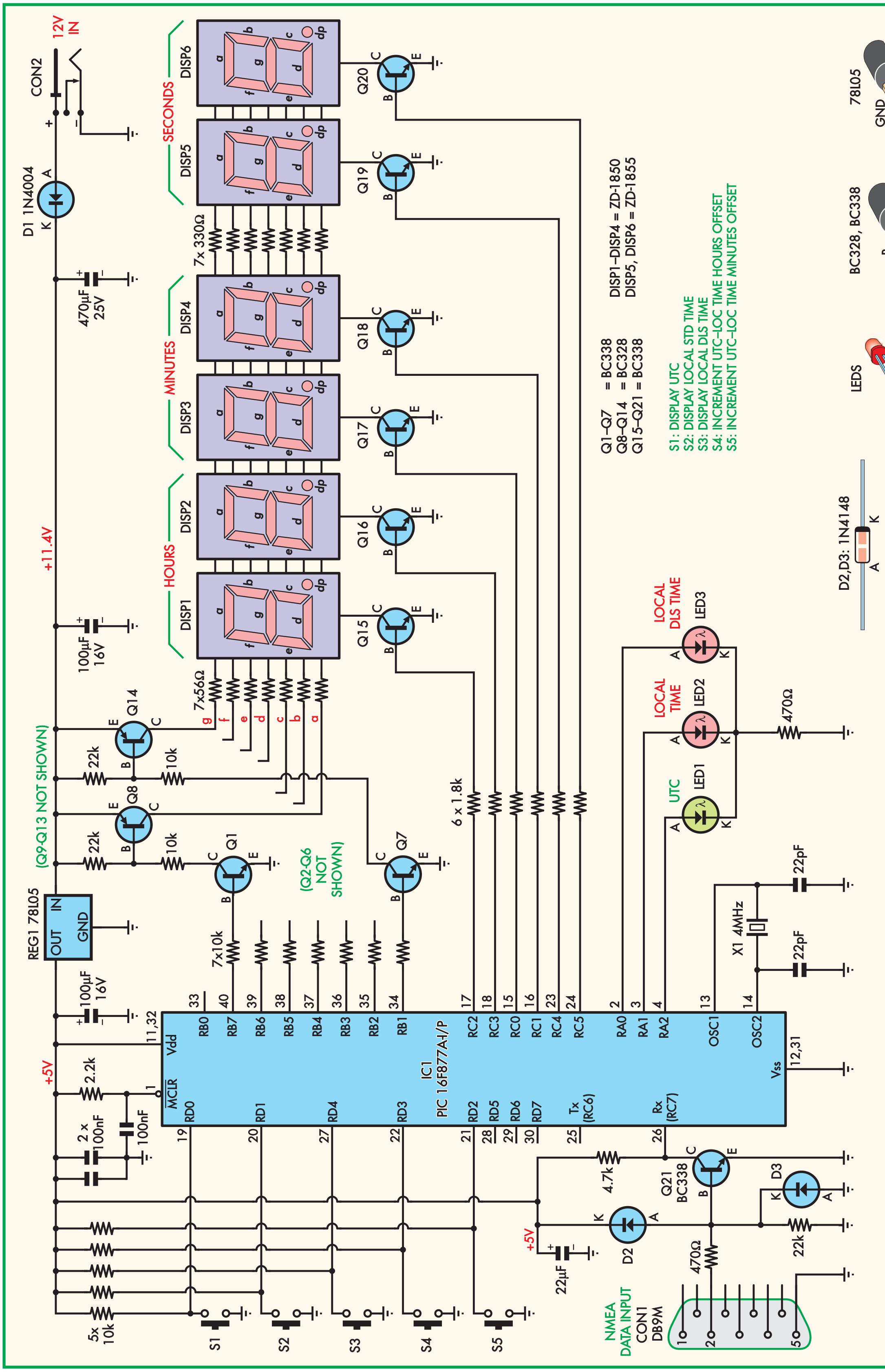
As it turned out, many readers were more interested in the timekeeping aspects of the GPS-based frequency reference, rather than its very accurate frequency outputs. They also wanted a much larger display that could be read at a distance. And they wanted the display to automatically show both local standard time and local daylight saving time.

The GPS-corrected clock in the March 2011 issue only added to the interest, with more readers asking for a GPS Digital Clock. So here it is.

It uses a microcontroller to calculate both standard and daylight saving times and display the result on a bright 6-digit LED display. 'Jumbo' 7-segment 58mm-high digits are used for the hours and minutes indication, while 13mm-high digits provide the seconds indication.

In operation, the circuit is designed to accept the 'NMEA 0183' data stream output from the external GPS receiver module. The microcontroller then extracts the UTC time information and uses it to work out the local standard and daylight saving times.

You decide whether UTC, local standard time or daylight saving time is displayed simply by pressing one of the three time-select buttons. The two remaining buttons are used only once, to initially set the UTC-local time offset.



6-DIGIT GPS CLOCK/TIME READOUT

Fig.1: the circuit is based on a PIC16F877A microcontroller. This processes the NMEA 0183 serial data from the GPS receiver module (at its pin 26 input) and drives six 7-segment LED displays in multiplex fashion. Switches S1 to S3 select the time format, while S4 and S5 are used to initially set the offset from UTC time.

How it works

Refer now to Fig.1 for the full circuit diagram. It employs a microcontroller (IC1), six 7-segment LED displays, 21 transistors, five pushbutton switches and a handful of other parts.

Virtually all of the work is done by the programmed PIC16F877A-I/P microcontroller (IC1). This accepts the NMEA 0183 serial data stream from the GPS receiver module (via CON1) and processes the data's GPRMC sentences to extract the UTC time information.

From this information, it works out the equivalent local standard and daylight saving times and continuously updates all three times in its memory. When you select which time you want to display (using switches S1, S2 or S3), it displays that time continuously on LED displays DISP1 to DISP6.

The PIC runs from its own internal clock oscillator, which has its frequency set by a 4MHz crystal (X1) connected between pin 13 and pin 14. The two 22pF capacitors provide the correct loading for the crystal, to ensure reliable starting of the oscillator.

The displays are driven by the microcontroller in multiplex fashion via transistors Q1 to Q20. Q1 to Q14 are driven by outputs RB1 to RB7, and in turn drive the display segments (a to g). Transistors Q15 to Q20 drive the common display cathodes. These transistors are switched by IC1's RC0 to RC5 outputs.

LED1 to LED3 indicate which time mode is currently being displayed. These LEDs are directly driven by IC1's RA0 to RA2 outputs, and have a common 470Ω current-limiting resistor.

Data stream

In greater detail, the NMEA 0183 serial data stream from the GPS receiver module arrives at pin 2 of DB9M connector CON1. Because it has the same polarity as normal RS-232C data, it's passed through a simple inverter stage, based on transistor Q21, and then fed into pin 26 (RC7/Rx) of the microcontroller. This pin is the data input for the micro's USART module.

By the way, if you want to see what the NMEA 0183 data stream from a GPS receiver looks like, a sample is shown in Fig.2. This shows three of the sentences sent out by a typical GPS receiver every second, at 4800bps.

The sentence, which begins with the ID '$GPRMC' is the one we are interested in here. It's provided by just about all GPS receivers and contains the UTC time data we want right 'up front' (ie, in the first field following the ID code). In the GPRMC sentence shown, the UTC time field is 231034, which indicates that the UTC time at that instant was 23 hours, 10 minutes and 34 seconds. The current date information is also visible near the end of the sentence, ie, '120309', indicating March 12, 2009.

In this project the program running in the PIC extracts this UTC time information from each GPRMC sentence and saves it in memory. It then works out the equivalent local standard time, by adding the time offset for your time zone (this information is initially fed in via switches S4 and S5) and this is also saved. And finally, it works out the corresponding daylight saving time and saves this as well.

Once all three times have been updated, the program in IC1 then checks to see which time standard is currently being displayed. It then displays this time on displays DISP1 to DISP6, driving the display segment lines from its RB1 to RB7 PORTB via transistors Q1 to Q14.

As indicated earlier, the individual 7-segment displays are switched on and off in sequence via transistors Q15 to Q20. These are driven by IC1's RC0 to RC5 PORTC pins.

As part of its operation, the program also scans switches S1 to S5. If a switch has been pressed, it pulls its corresponding input (RD0 to RD4) low and this is detected by the program. As a result, IC1 either changes the display mode setting (S1 to S3 pressed) or changes the stored time offset setting (S4 to S5 pressed).

The new settings are then saved in the PIC's EEPROM memory, so they are not lost if the power is removed.

Power supply

Power for the circuit is derived from a 12V DC plugpack supply and is applied to the circuit via DC connector CON2 and reverse polarity diode D1. The resulting 11.4V (nominal) rail is then filtered using a 470µF electrolytic

Building a self-contained clock

You don't need to build the GPS-Based Frequency Reference described in the April-May 2009 issues of *EPE*. Instead, you can derive the required NMEA 0183 data from a low-cost GPS receiver module and use that to drive the display readout.

In particular, the GlobalSat EM-408 receiver module is ideal for this application. This GPS module was also used by Geoff Graham in the GPS-Synchronised Analogue Clock described in the March 2011 issue and is readily available.

The GlobalSat EM-408 GPS module.

It's quite easy to use the EM-408 GPS module. Accordingly, we have produced a compact add-on board containing this module, which connects directly to the display unit. It can either fit inside the same case as the display board (and be wired directly to it) or installed in a separate case and connected via the DB9 connector.

An advantage of the EM-408 GPS module is that it has a self-contained antenna and is extremely sensitive. As a result, it works perfectly well indoors without the need for an external antenna and associated cabling.

The add-on GPS module will be described in Part 2 in the June 2011 issue of *EPE*.

NMEA 0183 DATA STREAM

$GPRMC,231034,A,3356.3399,S,15108.2790,E,000.0,010.0,120309,012.6,E*63
$GPGGA,231034,3356.3399,S,15108.2790,E,1,10,1.0,57.3,M,19.6,M,,*65
$GPGSV,3,3,11,23,45,051,43,25,60,156,45,28,18,320,36*4F

Fig.2: three of the sentences sent out each second by a typical GPS receiver. The one starting with '$GPRMC' has the UTC time information.

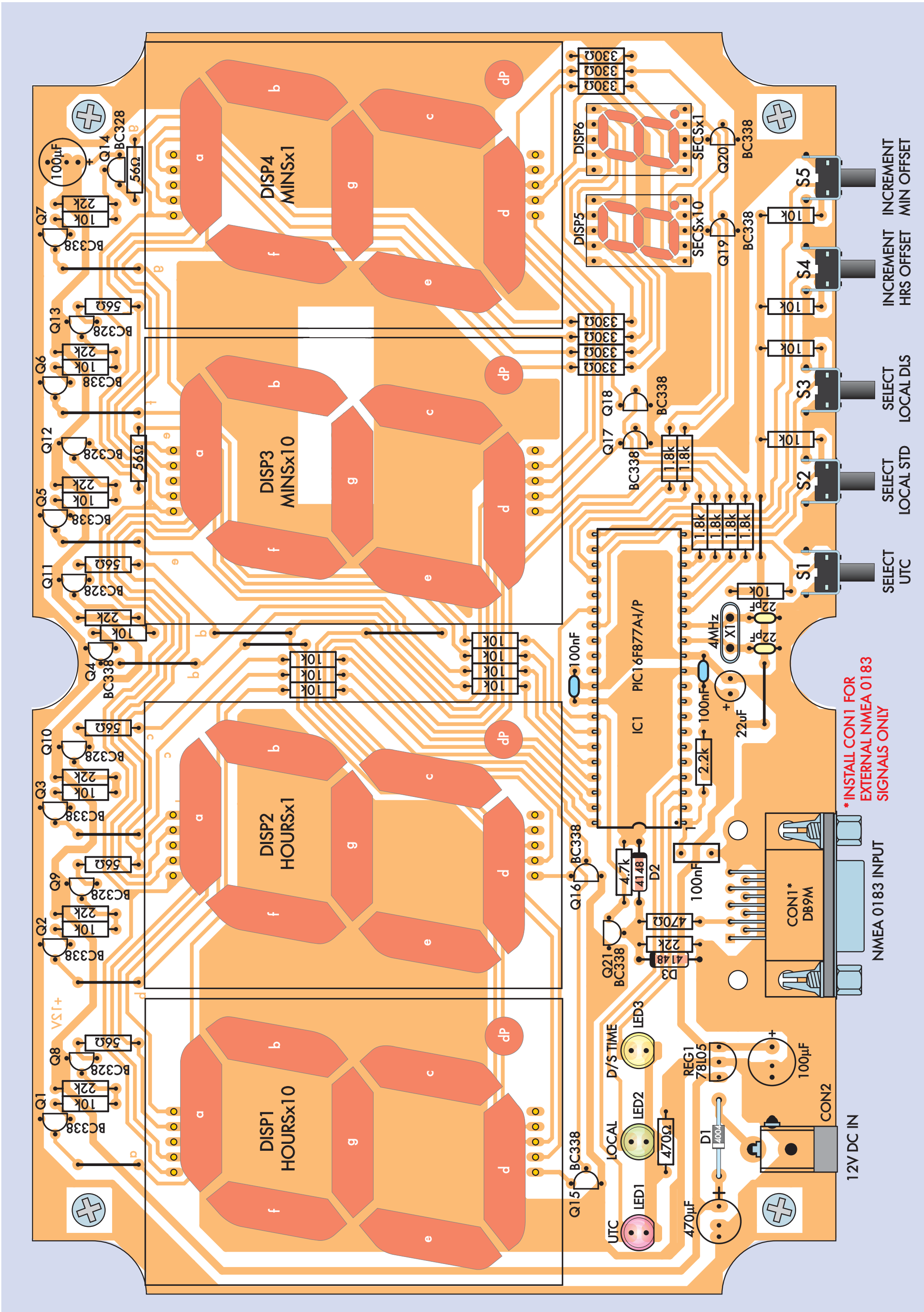
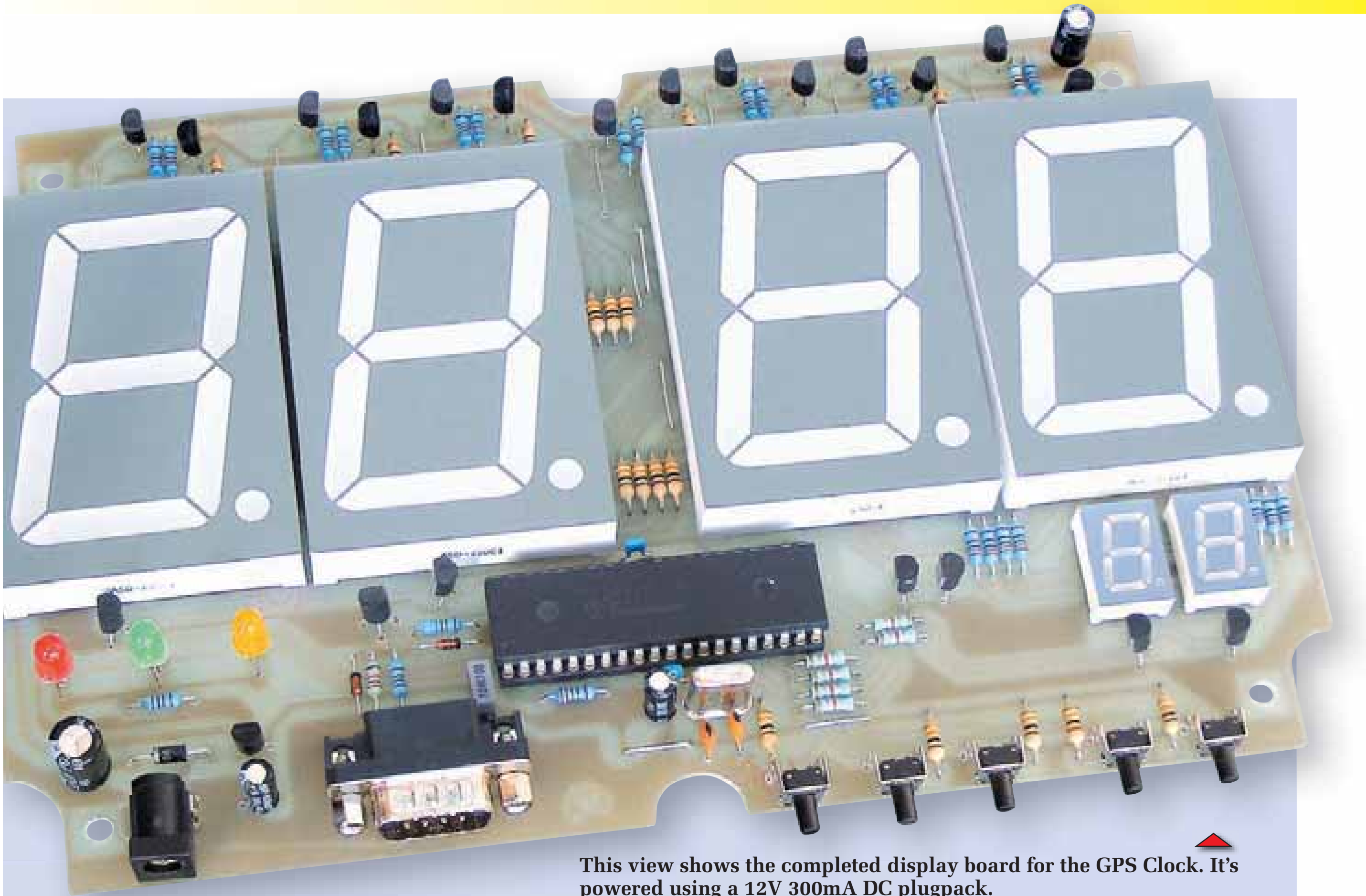


Fig.3: install the parts on the PC board as shown in this layout diagram. Make sure that all parts, including the displays, are correctly orientated and install CON1 only if you intend deriving the GPS time signals from an external unit such as the GPS Frequency Reference.

capacitor and used to power the 7-segment displays DISP1 to DISP6.

The PIC microcontroller (IC1) and inverter stage Q21 operate from a +5V rail. This is derived from the +11.4V line via 3-terminal regulator REG1, a low-power 78L05 device. A 100µF capacitor filters the output of the regulator, with additional filtering provided by a 100nF capacitor.

That's all there is to it. Now let's look at the construction.



This view shows the completed display board for the GPS Clock. It's powered using a 12V 300mA DC plugpack.

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	7	22kΩ	red red orange brown	red red black red brown
❏	19	10kΩ	brown black orange brown	brown black black red brown
❏	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❏	1	2.2kΩ	red red red brown	red red black brown brown
❏	6	1.8kΩ	brown grey red brown	brown grey black brown brown
❏	2	470Ω	yellow violet brown brown	yellow violet black black brown
❏	7	330Ω	orange orange brown brown	orange orange black black brown
❏	7	56Ω	green blue black brown	green blue black gold brown

Construction

As shown in the photos, all the display circuitry is mounted on a single PC board. This fits snugly inside a standard plastic enclosure with a clear lid. The PC board measures 211mm × 135mm and is coded 800. This board is available from the *EPE PCB Service*. The software files will be available for free download via the *EPE Library* site at: **epemag.com**.

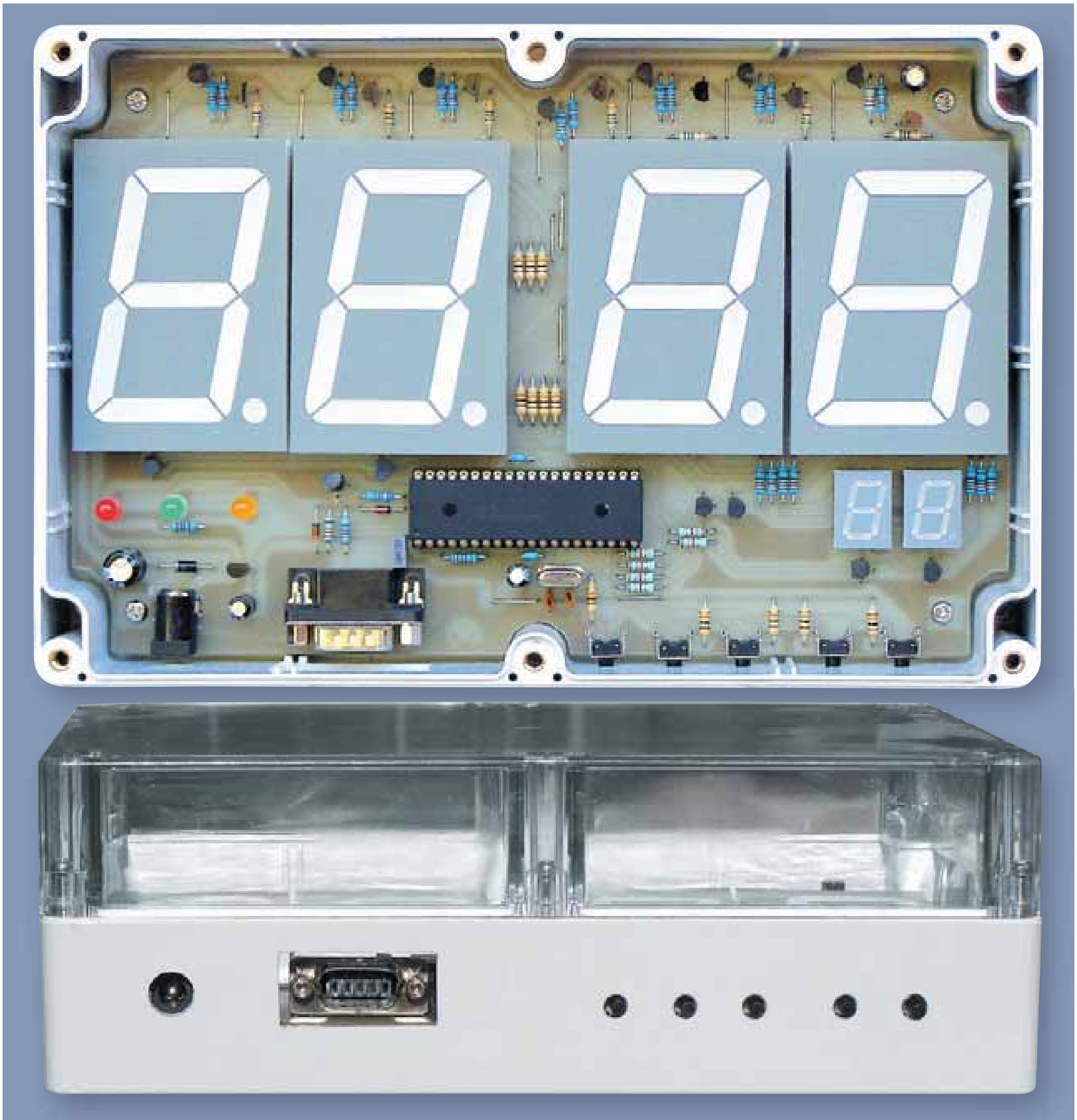
Fig.3 shows the parts layout. Begin construction by carefully inspecting the PC board for any etching defects. Check also that the four corner mounting holes are drilled to 3mm.

That done, the next step is to fit the 12 wire links and the resistors. Table 1 shows the resistor colour codes, but check each one with a digital multimeter before installing it, just to make sure.

Follow these parts with the capacitors – first the non-polarised ceramics and the MKT unit, then the four larger electrolytics. The latter are polarised, so make sure you fit them with the polarity shown on Fig.3. Crystal X1 can then be installed, followed by diodes D1-D3 (watch their polarity!).

CON1, CON2 and the five mini pushbutton switches (S1 to S5) are next on the list. **However, note that you will only have to install CON1 (the DB9 connector) if you are using an external source for the GPS time signals (eg, the GPS-Based Frequency Reference).** If you build the add-on GPS module to be described next month, it can fit inside the same case as the display board and be wired directly to it.

Next, install the 40-pin socket for IC1. Make sure you fit the socket with



If you intend using an external source of GPS time signals, then the display board can be installed in the bottom of the case, as shown in the top photo. Holes are drilled/cut along one side (see photo above) to provide access to the switches, DC power socket and DB9 connector.

its 'notched' end to the left, to guide you when you later plug in the micro itself. Regulator REG1 can then be installed, taking care to orientate it exactly as shown.

The 21 transistors are next on the list. Note that these are a mixture of BC338 *NPN* and BC328 *PNP* types, so take care here. The BC338s are used for Q1 to Q7 and Q15 to Q21, while the BC328s are used for Q8 to Q14. If you accidentally swap any of these transistors you'll get some strange results, like missing segments or digits.

After the transistors, fit the four jumbo displays DISP1 to DISP4, followed by the two smaller displays DISP5 and DISP6. These are all polarised, and it's important to fit each one with its decimal point LED at lower right. We don't actually use the decimal points in this design, but if you don't fit each display correctly, it simply won't work.

Make sure that each display is sitting flush against the PC board before soldering its pins.

Atomic clock standard via GPS

It's not long ago that a really accurate time display based on a caesium-beam 'atomic clock' was something only standards labs could consider. The rest of us had to rely on time signals from shortwave or VLF radio stations, which gave only 'reasonable' accuracy.

This all changed when the US military set up its Global Positioning System (GPS). That's because every GPS satellite contains two caesium-beam clocks, which are used to ensure the system's navigational accuracy. These satellites broadcast an updated digital UTC (Universal Time Coordinated) time signal every second, which means that you can obtain an extremely accurate time display simply by decoding the time information from a GPS receiver.

This includes the receivers used inside GPS navigator devices. As a result, many such units can either display the time continuously or on demand.

The three indicator LEDs (LED1 to LED3) are next on the list. These are mounted vertically, with their cathode (K) leads towards the bottom of the board and their bodies about 10mm above the board so that they're clearly visible. Use a red LED for LED1, a green LED for LED2 and an orange/yellow LED for LED3.

Once the LEDs have been fitted, all that remains to finish your GPS time display board is to plug the programmed PIC micro (IC1) into its socket. Take care to plug it in with its notched pin1 end towards the left, as shown on the parts layout diagram (Fig.3). The completed board assembly can then be placed aside while you prepare the enclosure.

Preparing the enclosure

Fig.4 shows the drilling details for the case. **Note, however, that this diagram applies only if you are mounting the unit in the base of the case and feeding in the GPS time signals via CON1 (the DB9 connector) from an external source.** If you elect to build the add-on GPS module (described in Part 2) and install it in the same case, this will require a slightly different mounting arrangement for the display board (details next month).

As shown in Fig.4, all the holes are along one side of the base. You have to drill five 5mm holes for the switches, plus a 10mm hole to provide access to the DC power socket. In addition, a 34mm × 16mm cut-out is necessary to access the on-board DB9M connector.

You can either use Fig.4 to mark out the case for drilling or it can be copied and temporarily attached to the side of the case for use as a drilling template. Use a small pilot drill to drill each hole first, then carefully enlarge it by stepping up the drill size. The 10mm hole is best enlarged to size (from about 5mm) using a tapered reamer.

The square cut-out is made by drilling a series of small holes around the inside perimeter, then knocking out the centre piece and carefully filing the job to a neat finish.

The PC board can now be installed in the case. To do this, first position four M3 x 6mm untapped spacers on top of the four corner mounting pillars moulded into the bottom of the enclosure. That done, you then have to slowly lower the board into the case without disturbing these spacers.

Note that you will have to angle the switch side of the board down as its lowered into the case, so that the switch actuators go through their holes. Once it's in position, secure the board in place by fitting an M3 x 10mm machine screw to each corner position. Fig.5 shows the details.

All that remains now is to attach the clear top of the enclosure, using the six screws supplied. There's no real need to fit the supplied rubber sealing strip between the two halves of the enclosure, but you can fit it if you wish.

Putting it to work

No adjustments are required – it's just a matter of feeding in the serial data from the GPS module described next month (or from the GPS-Based Frequency Reference) and applying power. You'll need a standard DB9M-DB9F serial cable to make the connection to CON1. In addition, a 12V DC plugpack capable of supplying at least 160mA will be necessary to power the unit (eg, a 12V DC 300mA unit).

As soon as power is applied, the displays should begin indicating UTC time (this can take anywhere from a few seconds up to about 40s), with LED1 lighting to show that this is

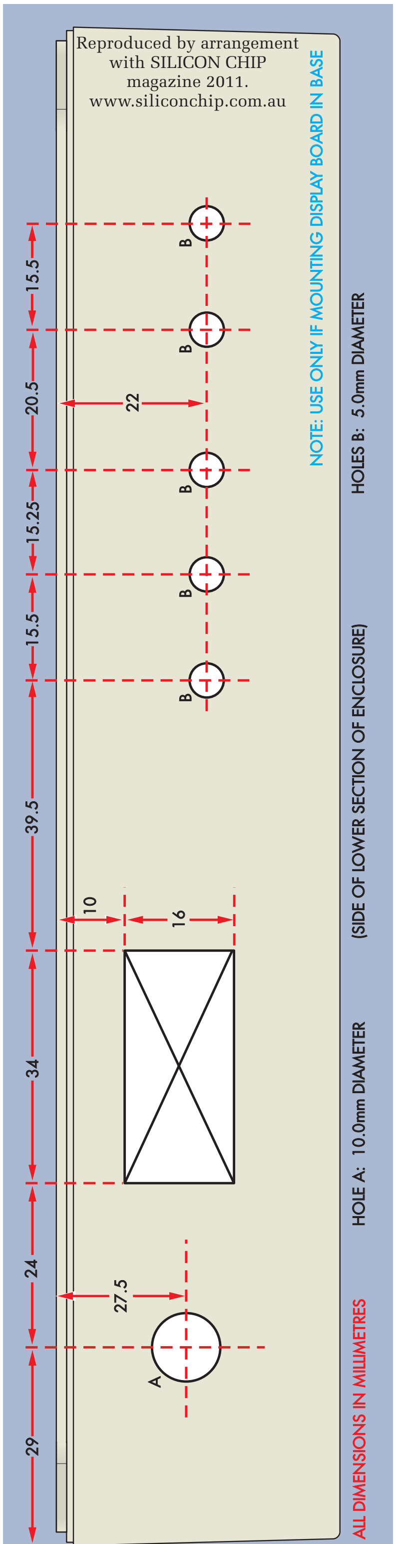


Fig.4: follow this case drilling diagram only if you intend feeding in the GPS time signals from an external source – see text.

Parts List

1 PC board, code 800, this board is available from the *EPE PCB Service*, size 211mm × 135mm
1 polycarbonate enclosure, 222 × 146mm × 75mm, with clear lid (Jaycar HB-6258 or similar)
5 PC-mount 90° momentary mini SPST pushbutton switches (S1-S5)
1 4MHz crystal (X1)
1 PC-mount DB9M connector (CON1) – see text
1 PC-mount 2.5mm concentric DC plug (CON2)
1 40-pin DIL IC socket, 0.6-inch spacing
4 M3 × 6mm untapped nylon spacers
4 M3 × 10mm screws, pan head
1 300mm length of 0.7mm tinned copper wire (for links)

Semiconductors
4 7-segment displays (CC) with 58mm high digits (Jaycar ZD-1850) (DISP1-4)
2 7-segment displays (CC) with 13mm high digits (Jaycar ZD-1855) (DISP5-6)
1 PIC16F877A-I/P pre-programmed microcontroller (IC1)
1 78L05 +5V regulator (REG1)
14 BC338 transistors (Q1-Q7, Q15-Q21)
7 BC328 transistors (Q8-Q14)
1 5mm red LED (LED1)
1 5mm green LED (LED2)
1 5mm orange LED (LED3)
1 1N4004 1A rect. diode (D1)
2 1N4148 signal diodes (D2,D3)

Capacitors
1 470µF 25V radial electrolytic
2 100µF 16V radial electrolytic
1 22µF 16V radial electrolytic
1 100nF MKT polyester
2 100nF multilayer monolithic
2 22pF NPO disc ceramic

Resistors (0.25W 1%)

8 22kΩ	6 1.8kΩ
19 10kΩ	2 470Ω
1 4.7kΩ	7 330Ω
1 2.2kΩ	7 56Ω

the current display mode. This is the default start-up mode when the unit is powered up for the very first time.

Assuming that it's working so far, try pressing S2. LED2 should now begin glowing instead of LED1, and the displays should swing over to local standard time. Initially, this will be local standard time for eastern Australia (EAST), because that is also the default setting (ie, an offset of +10 hours). However, this offset can be easily changed to suit your own time zone, as detailed shortly.

For the present, just try pressing S3. This should bump the time forward by an hour to show local daylight saving time. Of course, this third time variant may or may not be of any interest to you, depending on both the time of year and whether your region observes daylight saving.

What if you live in another country, where the time zone is quite different? In that case, how do you set the display's offset so it will display the correct local standard and daylight saving times for your location?

In practice, it's quite easy – just briefly press switch S2 (so that the unit shows local standard time), then press S4 a number of times until the hours indication is correct for your local time (NOT daylight saving time).

You'll find that each time you press S4, the display will blink and the hours indication will increment by one – up to a maximum of 23, when the hours display will drop back to 00 and then begin climbing again.

In most cases, repeatedly pressing S4 (to get the correct hours indication for local time) is all you need to do to set the offset from UTC. However, if you live in places like South Australia or the Northern Territory, where the offset has a 30-minute component as well, you'll also need to press S5. This increments in 30-minute steps, so you'll only have to press it once.

As a matter of interest, we've prepared a table (Table 2) showing the offsets for all states and regions of Australia plus those for New Zealand, various countries in Asia, regions in the USA and Canada and a few others. Alternatively, look up your timezone at: **http://worldtimezone.com**.

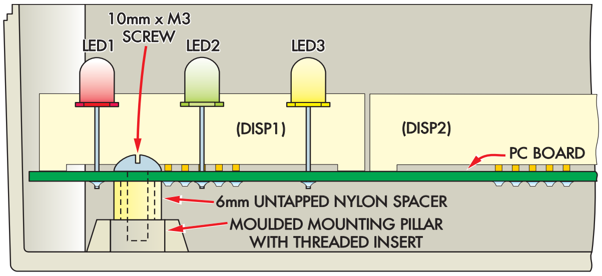


Fig.5: the display board is mounted inside the case on 6mm untapped nylon spacers and secured using M3 × 10mm machine screws.

UTC-LOCAL STD TIME OFFSETS

STATE, REGION OR COUNTRY	OFFSET (HOURS)
New South Wales (except Broken Hill)	+10
Queensland, Victoria, Tasmania, ACT	+10
South Australia, NT, Broken Hill	+9.5
Western Australia	+8
Papua New Guinea	+10
New Zealand, Fiji	+12
Indonesia (West, East)	+7, +8
China, Hong Kong, Taiwan, Singapore	+8
Japan, Korea	+9
India	+5.5
Pakistan	+5
Saudi Arabia, Dubai	+3
Russia (West – East)	+3, +4 – +11, +12
South Africa	+2
France, Spain, Italy, Scandinavia	+1
United Kingdom, Portugal	0
USA and Canada (West – East)	–4, –5, –6, –7, –8
Mexico	–6
Argentina, Brazil	–3
Columbia, Ecuador, Peru	–5
For further information visit http://worldtimezone.com	

Table 2: The offsets from UTC time for various regions throughout the world.

In most cases, the offset is simply a certain number of hours, depending on the longitude east or west of the Greenwich meridian, which is used to reference UTC. Only in a small number of cases does the offset involve minutes as well as hours (eg, South Australia and the Northern Territory, where the offset is 9 hours and 30 minutes).

Saving the settings

Each time you press any of the five switches S1 to S5, the micro not only responds in the desired way, but also saves the current settings in its non-volatile EEPROM memory. This means that once set, you don't have to reset the offset again, even if the power is lost. The only time you do have to reset the offset is if you move to a location in a different time zone.

Next month, we'll describe the add-on GPS module.

EPE EXCLUSIVE

Win a Microchip enhanced mTouch Capacitive Touch Evaluation Kit

EVERYDAY PRACTICAL ELECTRONICS is offering readers the chance to win a Microchip enhanced mTouch Capacitive Touch Evaluation Kit. The enhanced mTouch Capacitive Evaluation Kit (P/N DM183026-2) provides a simple platform for developing a variety of capacitive touch sensing applications using PIC16F, PIC24F, PIC18F and PIC32 microcontrollers. The Diagnostic Tool provided allows the user to analyse application-critical information in real-time, as it relates to touch sensor behaviour.

The enhanced mTouch Capacitive Touch Evaluation Kit includes a new board for development with the PIC32. It comes equipped with capacitive touch-sensing keys and sliders, which allows designers to evaluate this interface in their applications using the Windows OS-based mTouch Diagnostic Tool.

This software tool provides an easy-to-use graphical user interface (GUI) for developing cap-touch buttons and sliders, and is included in the free MPLAB Integrated Development Environment. The additional software libraries, source code and other support materials that come with the board further shorten development cycles and reduce design costs.

The enhanced kit now contains:

- Four motherboards, featuring PIC16F1937, PIC18F46J50, PIC24FJ64GB106 and PIC32MX795F512H microcontrollers.
- Four sensor daughter boards consisting of a Direct 8-Key Board, 12-Key Matrix Sensor Board, 4-channel Slider Sensor Board and 2-Channel Slider Sensor Board.
- A PICkit Serial Analyser
- USB cable.

WORTH $99.95 (approx. £62.00) EACH

CLOSING DATE

The closing date for this offer is 30 June 2011

HOW TO ENTER

For your chance to win a Microchip enhanced mTouch Capacitive Touch Evaluation Kit, visit **www.microchip-comps.com/epe-encap** and enter your details in the online entry form.

Any sensor that outputs a varying voltage can be used by the Simple Voltage Switch to turn things on and off ... intercooler sprays, boost control solenoids, warning lights, fans, water injection – you name it!

Design by JOHN CLARKE

Simple Voltage Switch For Car Sensors

This Simple Voltage Switch can be used anywhere you want a relay to switch when a voltage reaches a preset level. It has lots of applications in cars, but can be used in any application where you have 12V DC available. Having switched the relay on, it will then switch if off as the voltage being monitored drops below the preset level.

IN CAR applications, many engine sensors have variable voltage outputs, and these can be used for relay switching. For example, if your car has an air-flow meter with a voltage output (most cars have), then you can use that as an engine load signal to switch things on and off.

Main features

- Adjustable switching level, between 0V and 16V at input
- DPDT 5A relay
- Configurable to switch on rising or falling voltage
- Adjustable hysteresis
- High input impedance – won't load sensor outputs

Possible applications

For example, do you want a warning when fuel usage is going through the roof, as it will be when the air-flow is high? If you use this project, it can turn on a light and/or sound a buzzer so you can ease off on the accelerator or change down a gear, or both.

Or you could use the throttle position sensor directly, to do the same thing. Or going back to the air-flow sensor, in a turbocharged engine, you could use the Simple Voltage Switch to run a solenoid to close off the turbo waste from the boost pressure source whenever engine loads are low.

Or maybe, you could use the unit to control a water spray onto the intercooler. We are sure that you will be able to think of plenty of nifty ideas.

This project is quite simple in presentation; just a PC board with a relay and a handful of other components. You should be able to assemble it in less than an hour.

Circuit description

The full circuit of the Simple Voltage Switch is shown in Fig.1. It relies on comparator IC1a, which compares the input voltage to a preset reference level. The input voltage (V_{IN}) is divided via two 1MΩ resistors in series, which effectively apply one half of the voltage to the inverting input, pin 2, of

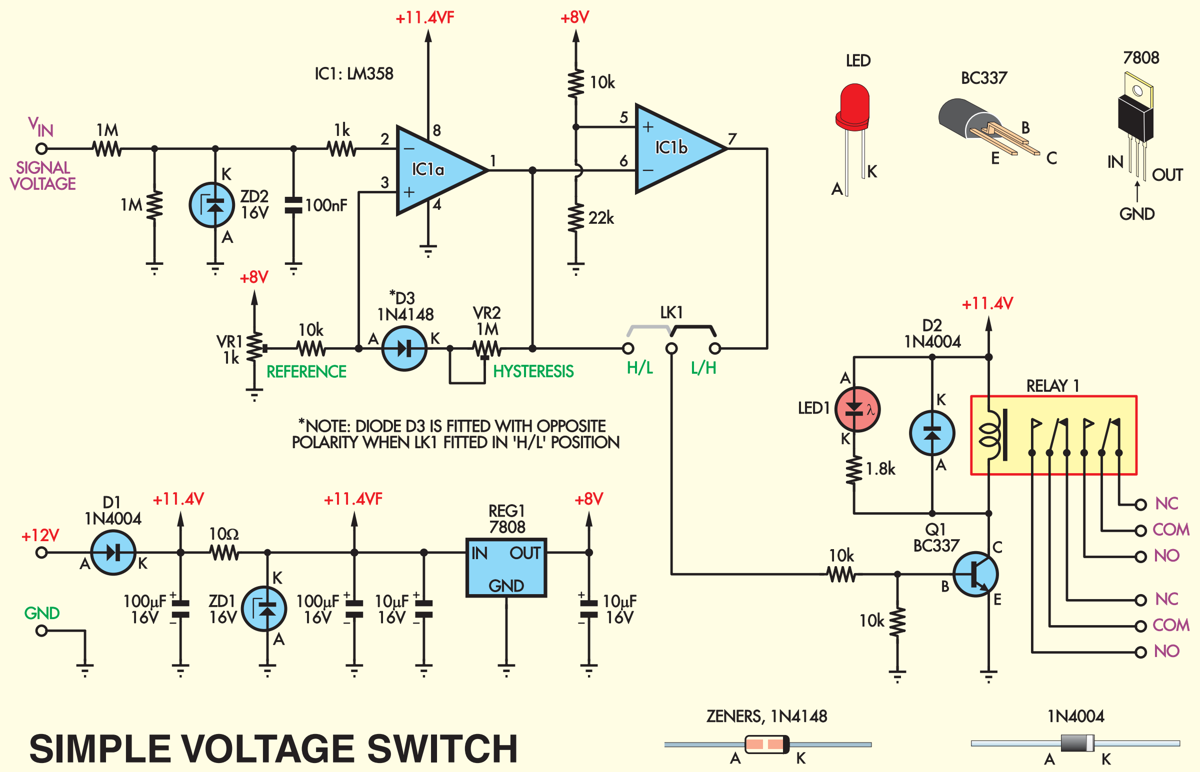


Fig.1: the circuit is based on comparators IC1a and IC1b. IC1a compares the input voltage (V_{IN}) to a reference voltage set by trimpot VR1, and switches its output (pin 1) high or low accordingly. IC1b acts as an inverter, while link LK1 allows the circuit to be set to trigger on either a rising voltage or a falling voltage. The selected comparator output drives transistor Q1 and the relay.

IC1a. Zener diode ZD2 and the 100nF capacitor are there to protect against transient voltages on the input signal.

IC1a's non-inverting input (pin 3) is connected to reference trimpot VR1, via a 10kΩ resistor. When pin 2 is above pin 3, IC1a's pin 1 output is low, ie, close to 0V. When pin 2 is below pin 3, pin 1 is high, at around +10V.

High or low

Hysteresis (positive feedback from pin 1 to pin 3) has been added to prevent the output from oscillating at the trigger voltage. This is provided via trimpot VR2 and diode D3.

This feedback causes the output to 'pull' the voltage at pin 3 either higher or lower, depending on whether the output at pin 1 is high or low, and also on the orientation of diode D3. If D3 is installed as shown (ie, anode (A) to pin 3), the voltage on pin 3 will be pulled lower than the reference voltage set by VR1 when IC1a's output (pin 1) goes low. However, if pin 1 is high, D3 will be reverse biased and the reference voltage is unaffected.

Conversely, if D3 is installed the other way around (cathode (K) to pin 3), then pin 3 will be pulled higher than the reference voltage if IC1a's output goes high.

In practice, this means that diode D3 is inserted with its anode towards pin 3 if you want the Simple Voltage Switch to trigger on a low-to-high (L/H) transition, and with its cathode towards pin 3 if you want it to trigger on a high-to-low (H/L) transition.

Basically, the hysteresis is the difference between the switch-on and switch-off voltages, and this is set using preset VR2. We need hysteresis in

Suggested uses for the voltage switch

- Intercooler water spray control (from air-flow meter, throttle position sensor or oxygen sensor signals)
- Anti-lag turbo wastegate control (operating a wastegate disconnect solenoid triggered from the air-flow meter signal)
- Nitrous oxide switching (from throttle position sensor signal)
- Intercooler fan control (from air-flow meter signal)
- Dashboard monitoring LED (eg, oxygen sensor output signal)
- Switching in and out engine management and auto transmission control modifications (from air-flow meter, throttle position sensor or oxygen sensor signals)
- Low battery voltage warning and/or disconnect

Parts List

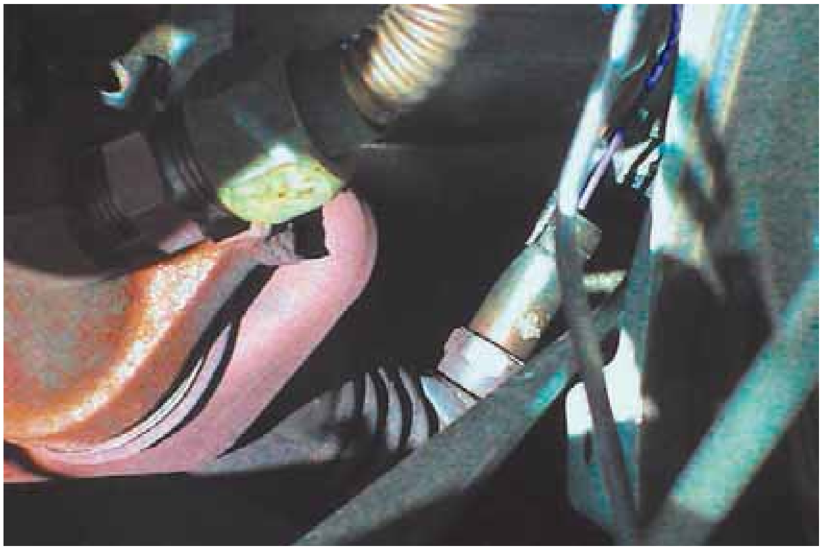
1 PC board, code 801, available from the *EPE PCB Service*, size 106mm × 61mm
5 PC-mount 2-way screw terminals, 5mm pin spacing
1 12V PC-mount DPDT 5A relay
1 3-way header, 2.54mm spacing
1 jumper shunt, 2.54mm spacing
1 1kΩ multiturn trimpot top adjust (VR1)
1 1MΩ preset, horizontal (VR2)

Semiconductors
1 LM358 dual op amp (IC1)
1 7808 3-terminal voltage regulator (REG1)
1 BC337 *NPN* transistor (Q1)
1 5mm red LED (LED1)
2 16V 1W Zener diodes (ZD1,ZD2)
2 1N4004 1A diodes (D1,D2)
1 1N4148 signal diode (D3)

Capacitors
2 100µF 16V PC electrolytic
2 10µF 16V PC electrolytic
1 100nF MKT polyester

Resistors (0.25W, 1%)

2 1MΩ	1 1.8kΩ
1 22kΩ	1 1kΩ
4 10kΩ	1 10Ω



The Simple Voltage Switch could be used to monitor the oxygen sensor signal, allowing devices to be turned on or off when the mixture is too rich or too lean. The unit won't load the signal, so it can still be used by the ECU.

the circuit, otherwise the relay would tend to switch on and off very rapidly when the input voltage is close to the preset threshold.

IC1b is an inverter, and it provides a signal which is the opposite polarity to IC1a's output. It compares IC1a's output with the +5.5V set on its non-inverting input. When IC1a's output goes high, IC1b's output goes low. And when IC1a's output goes low, IC2a's output goes high.

Link LK1 provides the option of driving the relay with a falling (H/L) input voltage, or a rising (L/H) input voltage, respectively. The output selected (either from IC1a or IC1b) drives transistor Q1, which in turn drives the relay.

The diode across the relay coil (D2) is there to quench the reverse voltage that is generated by the collapsing magnetic field of the relay coil when it is switched off. Without the diode, the relay could generate very high positive voltages, which could destroy the transistor.

Power for the circuit is obtained from the switched +12V ignition supply. Diode D1 gives reverse connection protection, while the 10Ω resistor, 100µF capacitor and Zener diode ZD1 provide transient protection at the input of regulator REG1.

The reference circuitry is powered from the output of REG1 (+8V), while the remainder of the circuit is powered from the +11.4V rails, which are derived before the regulator.

Construction

While the unit is simple to build, you need to know one thing about its eventual application. Will you be using it to detect a voltage that will be *increasing* (L/H) to the preset trip point, or *falling* (H/L) to the preset trip point? The unit can be made to work either way, but if you know this before you assemble it, there will be no need to make changes when it is ultimately installed.

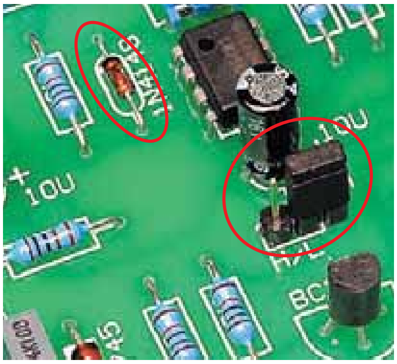
The low-to-high (L/H) voltage condition will be the most common, as in our example of switching an intercooler spray where the air-flow signal rises above a particular point, say 4V. Below 4V, the spray is off and above 4V, the spray comes on.

Ideally, you need to know which configuration you want before starting assembly. That way, you will know how to set the position of the link on the board, and the orientation of diode D3. On the other hand, if you do build and later decide to change the application, it is a simple matter of changing the link setting and the orientation of D3.

So, for a rising voltage detection, the moveable link LK1 is placed in the 'L/H' position, as shown in the component overlay diagram of Fig.2. Then diode D3 is orientated so that its cathode band is closest to the top of the board. For the opposite condition, detection of a falling voltage, the link

Resistor Colour Codes

Value	4-Band Code (1%)	5-Band Code (1%)
1MΩ	brown black green brown	brown black black yellow brown
22kΩ	red red orange brown	red red black red brown
10kΩ	brown black orange brown	brown black black red brown
1.8kΩ	brown grey red brown	brown grey black brown brown
1kΩ	brown black red brown	brown black black brown brown
10Ω	brown black black brown	brown black black gold brown



The placement of the link and the orientation of diode D3 (both circled here) will depend on whether you want to activate the switch on a rising voltage or a falling voltage. As shown here, the unit is configured to trigger on a rising voltage, which is the most common requirement. To trigger on a falling voltage, reverse the orientation of diode D3 and move the link to the H/L position.

is moved to its 'H/L' position and the diode's orientation is reversed.

Board assembly

The PC board topside component layout is shown in Fig.2. This board is available from the *EPE PCB Service*, code 801.

When assembling the PC board, we suggest that you start with the resistors and diodes, and then progress to the larger components. Carefully check each component value before you install it, and make sure that you insert the polarised components (diodes, IC, LED, transistor, voltage regulator and electrolytic capacitors) with the correct polarity.

Testing it

Test the kit at your workbench to make sure that it is working as it should. Do NOT be tempted to install it straight into your car, or other application, before you know that it is definitely working properly.

You will need a 12V battery or DC power supply and a variable voltage, to simulate the sensor output that the unit will be monitoring. The easiest way to do this is as shown in the photo on page 40 – it's just a matter of connecting a pot (eg, 10kΩ or more) across the supply, to give a 0V to 12V variable voltage at the wiper terminal.

Connect the DC supply and a potentiometer, as shown in the photo. Now rotate the potentiometer back

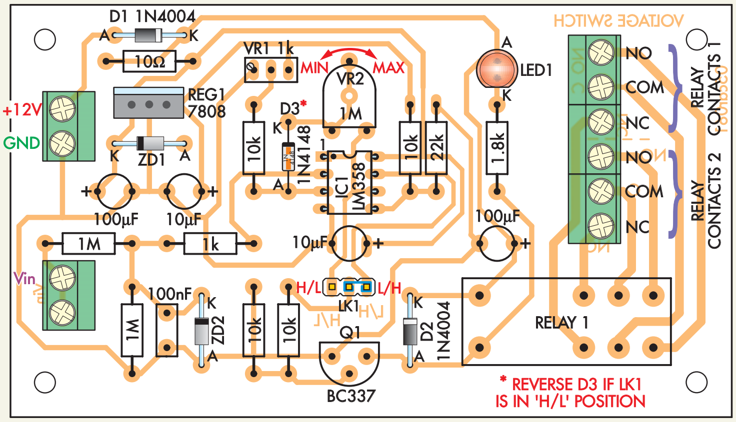


Fig.2: install the parts on the PC board as shown on this layout diagram. Don't forget to reverse D3 if LK1 is placed in the H/L position – ie, if you want the unit to trigger on a falling voltage instead of a rising voltage.

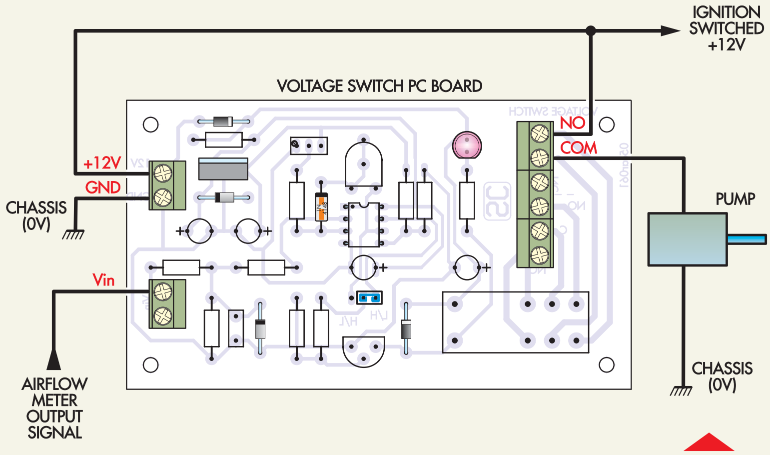
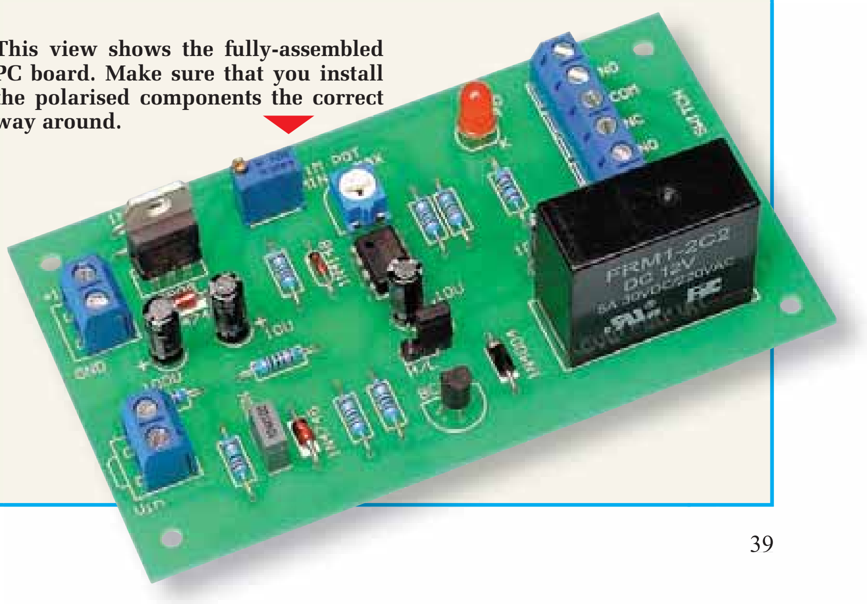
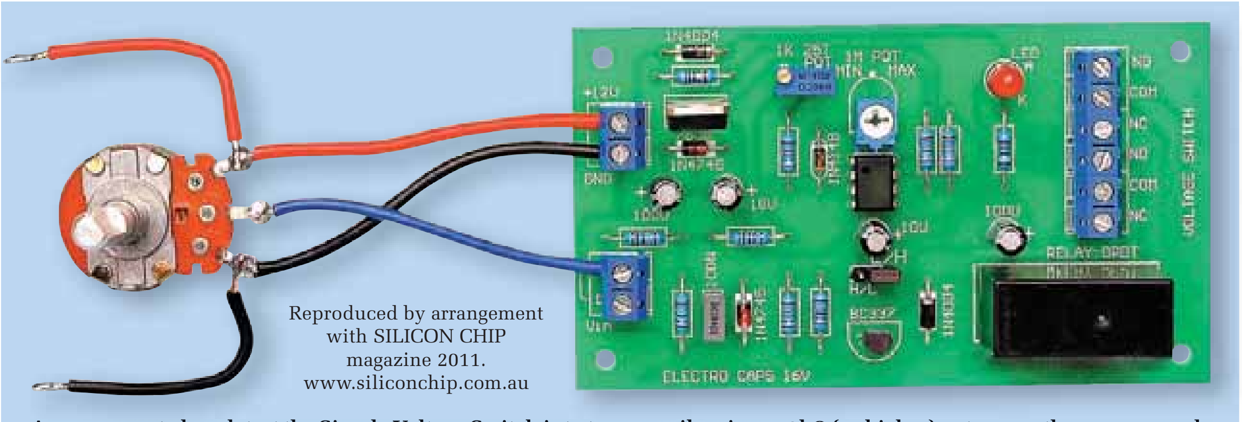


Fig.3: here is a typical set-up. The Simple Voltage Switch is connected to an ignition-switched +12V supply rail and to chassis, while the signal input is wired to the air-flow meter's output signal. One of the relay's normally open (NO) contacts is also connected to the ignition-switched +12V rail, while the adjacent common terminal is connected to an intercooler water spray pump. The other side of the pump is earthed. When the engine load exceeds a preset level, the water spray will be triggered into action.

This view shows the fully-assembled PC board. Make sure that you install the polarised components the correct way around.





An easy way to bench test the Simple Voltage Switch is to temporarily wire a 10kΩ (or higher) pot across the power supply to provide a variable signal voltage. An adjustable 0-12V will be available on the centre terminal of the pot. Here, the blue wire connects this variable voltage to the signal input of the Simple Voltage Switch. Connect the +12V and earth terminals to the red and black wires respectively and you can easily test the operation of the device.

and forth over its full range. At some point as you are rotating the potentiometer, the relay should click and LED1 should turn on or off. Rotating the potentiometer back the other way should again make the relay click and switch LED1 back off.

Using a multimeter, measure the voltage at the signal input (ie, connect the positive probe of the multimeter to the signal wire and the negative probe to earth) and measure the voltage at which the unit is activating the relay. For example, with the unit arranged to read rising voltages, as you gradually raise the input voltage the unit might turn on at 6.00V.

Hysteressis setting

Very slowly reduce the voltage to see at what point the relay turns off. You might find that the latter voltage is 5.7V, meaning that the hysteresis (the difference between the switch-on and switch-off voltages) is 0.3V. Rotate VR2, the hysteresis pot, to make sure that the hysteresis changes. For example, with a switch-on voltage of 5.00V the switch-off voltage might now be only 4.96V; but a hysteresis of just 0.04V is making it too critical!

As you rotate VR2 clockwise, the hysteresis will increase. Note that changing the hysteresis will not change the trip point, allowing the two to be set individually.

Next, you can test VR1, which sets the trip point. As you turn VR1 clockwise, the trip voltage will increase. VR1 is a multiturn trimpot, so that the trip point can be set very precisely.

Installation

Fitting the unit to a car is straightforward. You will need to provide an ignition-switched +12V supply, earth (chassis) and the connection to the sensor signal you want to monitor. For example, if you are triggering the unit from the air-flow meter, you'll need to use the workshop manual and a multimeter to find this wire. You will need to confirm that it has a voltage on it that rises with engine load and you will need to drive the car to do this.

The device to be switched by the relay will be connected to the 'normally open' and 'common' relay contacts. Fig.3 shows these connections.

Note that because a double-pole, double-throw (DPDT) relay has been used, another independent circuit can be switched simultaneously. This other circuit can even turn off the second device as the first is switched on.

If you want to simply monitor a voltage, such as that from the oxygen sensor, you can delete the relay and mount the LED on the dashboard. In this way, the LED will come on when the fuel mixture is rich, flash when the mixture is oscillating in closed-loop mode, and turn off when the mixture is lean.

Setting it up

There are two ways of setting up the Simple Voltage Switch:

1) Measure the sensor voltage and then set up the unit on the bench to operate at this voltage. This will probably avoid any need for fine-tuning in the car.
2) Do the complete set-up in the car itself.

If you are using an oxygen sensor to trip the unit, then the first way is better. For example, if you want the unit to trip when the sensor signal rises above 0.6V, then set it up on the bench to do this. When you subsequently install the unit in the car, you will only need to make a small adjustment to VR1.

However, if you want to turn on a device when monitoring the air-flow meter, it's best to do it on the car, because the air-flow meter signal varies over a much wider range.

When setting up, set the hysteresis pot to its minimum setting (ie, fully anticlockwise) and then adjust the trip point until the unit triggers when you want it to. If the relay tends to chatter around the trip point, rotate VR2 clockwise to increase the hysteresis. When it is tripping at the correct voltage, check how long the device continues to operate as the voltage again drops (assuming the unit is set to trip on a rising voltage).

For example, if you are using the unit to trip an intercooler water spray on the basis of air-flow output, does the spray go off fairly quickly as the load again drops? In some applications, the hysteresis setting will be critical, while in other applications it won't matter much at all.

In most cases, once the unit has been set up, it won't need to be altered.

The PC board fits into a standard 130mm × 68mm × 42mm plastic box. When the system is working correctly the board can be fitted into the box and installed under the dash or wherever it is convenient. ***EPE***

Footnote: a kit for this project is available from Jaycar Electronics, Cat. KC5377.

Recycle It!

BY JULIAN EDGAR

www.julianedgar.com

Incredibly Sensitive Air Movement Detector

A FEW years ago, while browsing an international online auction site, I saw an instrument that intrigued me. Called an Alnor Velometer Jr, it's a handheld gauge that measures very slow air movement. In fact, it will measure air speeds down to just 25 feet per minute (0.127 metres per second). At the other end of the scale is a speed of 200 feet per minute (still only one metre per second).

So what use is such an instrument? It can be used to measure airflows from air-conditioning and central heating vents (for example, when setting variable ducts so that the air flows are equal), finding drafts within weather-sealed houses, and checking the airflow speeds and directions in fan-cooled equipment. I thought it such an interesting instrument that I bought it – and have since much enjoyed using it.

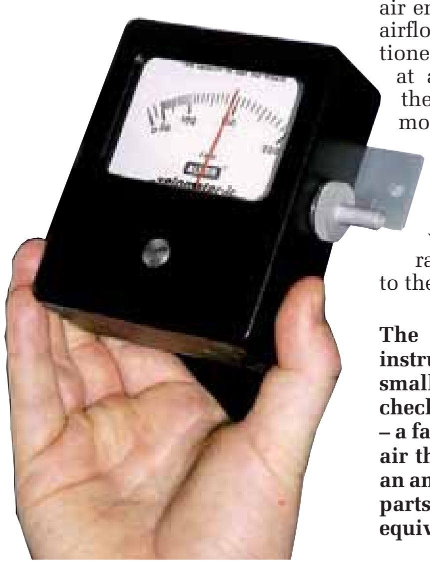
Why this prelude about the Velometer? Simply because it's very easy to make an electronic version of the instrument, one that is incredibly sensitive to tiny airflows – and yet, at the other end of the scale, will also measure air speeds of thousands of feet per minute.

Without (the rather difficult!) calibration, you won't be able to read off numbers in feet per minute, but you will be able to accurately measure relative airflows – and also have a fascinating gadget, sensitive enough to show the created air movement as you walk around a still room!

And cost? Well, the one I built cost nothing at all.

Hotwired

The heart of the instrument is a hot-wire airflow meter from the engine management system of a car. Hot wire airflow meters are used to measure the mass of air entering the engine. In this type of airflow meter a platinum wire is positioned in the airflow and is maintained at a high temperature. The greater the mass of air passing the wire, the more it is cooled and so the greater the current needed to maintain its temperature. The airflow meter's built-in electronics monitors this current requirement and outputs a voltage signal (normally within the range of 1V to 5V) that is proportional to the air mass flow.



The Velometer Jnr is a mechanical instrument capable of measuring very small airflows. Here it's being used to check airflow into a bonnet vent of a car – a fan inside the engine bay is drawing air through the vent. The Velometer is an amazing tool – but by using salvaged parts you can make your own electronic equivalent at nearly no cost!

Hot wire airflow meters started being used in cars in the mid-Eighties. At the time they were expensive to buy – and, in fact, new replacement units remain expensive. But you don't buy a replacement unit – instead you find a car being scrapped. These days, cars are often sent to the metal crusher with a host of good parts still intact, hot wire airflow meters amongst them.

The most commonly picked up hot wire airflow meter is the Bosch design shown on these pages. However, there are other designs around, including in more recent cars a very small assembly that inserts into an intake tube after the air filter.

Do NOT use a vane style airflow meter. You can recognise this design by its pivoting internal flap.

Hotwire airflow meters can often be found in 'orphan' form – that is, no

The hotwire airflow meter is fitted to many cars produced since the mid-1980s. It is used to measure the mass airflow being drawn into the engine. These meters are now available at very low (or zero) cost where cars are being junked. (Photo courtesy – Bosch)

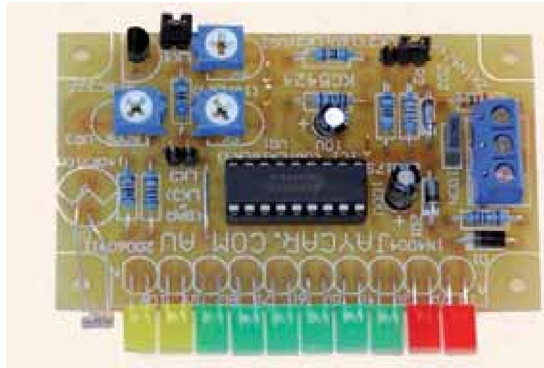
longer with the car or wiring loom they were sold with. Car dismantlers are much more likely to cheaply part with an airflow meter they know nothing about than one from a popular car. But without knowing the car (and having its workshop manual), how do you work out which connector pin is which? In fact, this is easier than it first appears – more on this in a moment. The airflow meter used in this story was picked up at the local rubbish tip.

Bosch hotwire airflow meters of the sort shown here will work off any voltage from about 6V to 15V, and the supply voltage doesn't need to be regulated. The meters draw about 0.5A. As indicated, the signal output is normally in the 1V to 5V range, where a higher output equals a greater mass flow (or, for our purposes, higher speed of air movement).

Monitoring the output

So how do you monitor the output? That's very much up to you and depends on what you want the design to achieve. Here are some alternatives:

- A digital voltmeter display can be used – this will show even minute changes in output, indicative of equally minute changes in air speeds! For really fine level of measurement, this approach is best.
- You can connect the output to an LED bargraph display – for example, the Jaycar Electronics KC-5424 kit, where you can set both high and low LED voltages, so expanding the sensitivity of the display and preventing any LEDs lighting until there is some airflow. You can also set this display to measure only the range of airflows you want, so for example being able to use the full scale with just room airflows.
- You can connect the airflow meter to a VU meter salvaged from an old cassette deck (just use a potentiometer (pot) as a voltage divider to reduce the signal output appropriately, this is described in more detail later). However, taking this approach will considerably reduce the displayed range of airflows and the meter will not be linear. But then again, it's easy and cheap and the flickering needle gets the point across very well that the airflow meter is doing something!



This Jaycar Electronics kit (cat no KC-5424) can be used to display the output voltage of the airflow meter. Because both upper and lower display voltages are adjustable, the display acts as an expanded scale, giving good resolution over the required range.

- Depending on the output voltage of the airflow meter when there is no air movement, and how high the voltage rises with expected air movement, you may be able to connect an LED and appropriate dropping resistor directly between the output wire and ground. The airflow meter shown here worked very well with a single LED – it would light faintly with some air movement and light brightly with a lot. Again, cheap and easy!
- Finally, I chose to mix two of the above approaches. I used dual LED VU meters salvaged from an old cassette deck. By using a multiturn pot, the LEDs could be adjusted so that with no air movement, the third LED in each display was just off. Then, with even the tiniest of air movements, the third LEDs would light-up. With still more airflow, the next few LEDs would light.

As with the mechanical VU meters, the display is non-linear, but it works brilliantly with my 'party trick' – getting people to enter a room and try to sit in front of the airflow meter without triggering the LEDs.

Sorting the pins

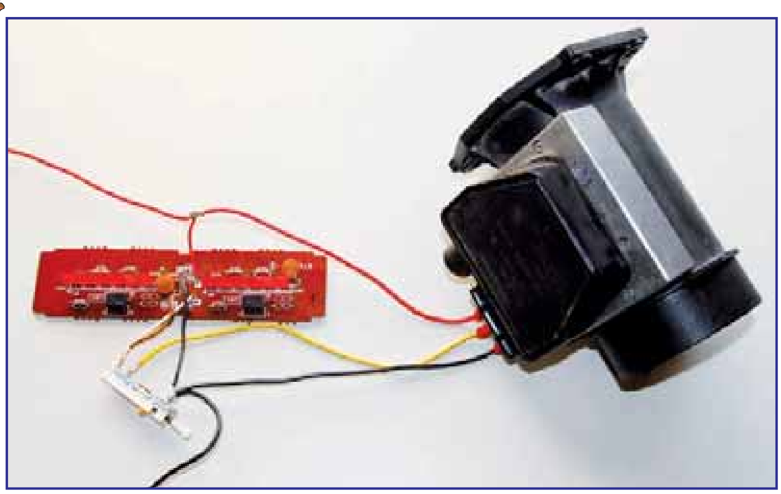
After you've obtained an airflow meter, the next step is to work out which pin on the connector is which. You may have assumed from the above description that airflow meters would have only three pins – ground, battery supply (that is, 12V nominal) and signal output.

Rat It Before You Chuck It!

Whenever you throw away an old TV (or VCR or washing machine or dishwasher or printer) do you always think that surely there must be some good salvageable components inside? Well, this column is for you! (And it's also for people without a lot of dough.) Each month, we'll use bits and pieces sourced from discards, sometimes in mini-projects and other times as an ideas smorgasbord.

And you can contribute as well. If you have a use for specific parts which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you have a use for the high-quality bearings from VCR heads. Or perhaps you've found how the guts of a cassette player can be easily turned into a metal detector. (Well, we made the last one up, but you get the idea…)

So, if you have some practical ideas, do write in and tell us!



Here the airflow meter is wired to a VU LED bargraph display taken from a salvaged cassette deck. The 50kΩ multiturn pot is also a salvaged part (and note that this pot's pin-outs varies from the normal type). Not shown is the plug-pack powering the system – it was also salvaged for nix. Total cost of the system? Nothing...

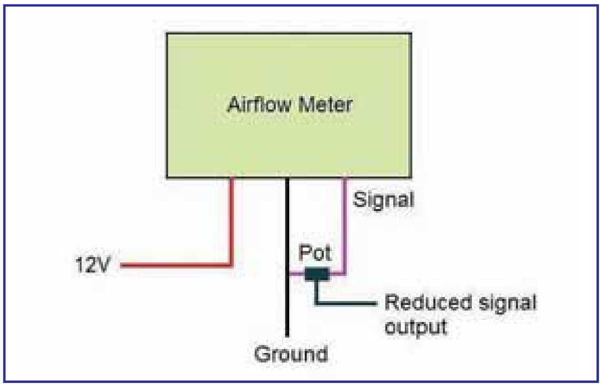
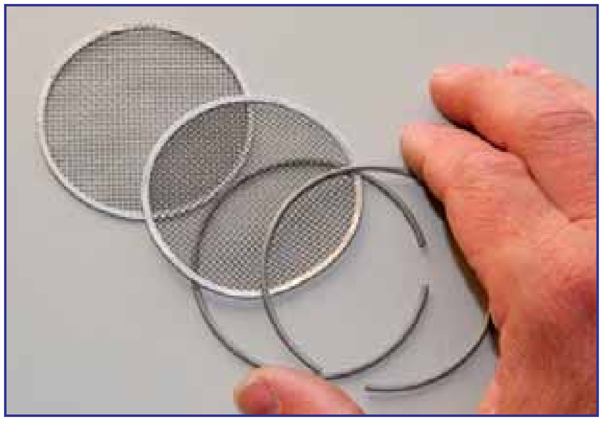


Fig.1. To reduce the output signal (for example to display the output on a VU meter salvaged from an old cassette deck) use a multiturn 50kΩ pot wired like this.



The sensitivity of the airflow meter can be improved by removing the front and rear screens.

However, it is, in fact, likely that there will be six or even seven pins. These include connections for (often) two grounds, an input that triggers the dirt burn-off function (where the platinum wire is heated red-hot for a short time after the engine is switched off), and an output sending intake air temperature information to the car's Electronic Control Unit.

The first step in finding which pin is which is to find the pin(s) that have continuity to ground – that is, to any metal part of the airflow meter body. On older meters, there is usually a metal casting surrounding the electronics, while others have metal cooling fins within the interior of the meter. The pin with continuity to ground is the *negative* battery connection. Another pin is likely to have about 3Ω resistance to ground – this pin should be left unconnected.

Using a current-limited power supply, with the limiting set to about 0.5A, connect the negative from the power supply to the airflow meter's ground terminal. Then connect the 12V supply in turn to the other terminals (but *not* the one that measured 3Ω to ground), at the same time, use a multimeter with one probe grounded and the other checking the outputs of the remaining pins. When the airflow meter is correctly powered-up, you should find one pin that has around 1V to 1.5V on it, which rises when you blow into the meter.

However, it's best to be honest – despite in-built protection of the airflow meter, during the above process it's still possible to destroy the airflow meter... so you want one that didn't cost you anything!

Incidentally, if you have not sourced the wiring harness and plug, just use miniature female spade terminals to make the connections to the airflow meter's pins.

Display meter

If you are using a display meter that has a full-scale deflection of less than the maximum signal you want to measure (that will apply to VU meters, both mechanical and LED), wire a 50kΩ multiturn pot, as shown in Fig.1. Multiturn pots are salvageable from many pieces of discarded equipment. Adjust the pot to give the required display behaviour. (As noted previously, this approach will not 'expand the scale' so if you want a zero reading with no air movement, and full scale with full air movement, use the Jaycar LED bargraph kit cited earlier.)

Power supply

Unless you use a rechargeable battery (eg, an SLA design), the ~0.5A current consumption means that the meter is best powered by a mains plug-pack. Any plug-pack capable of delivering the current and at the same time outputting a voltage from around 6V to 14V is fine.

Mechanical mods

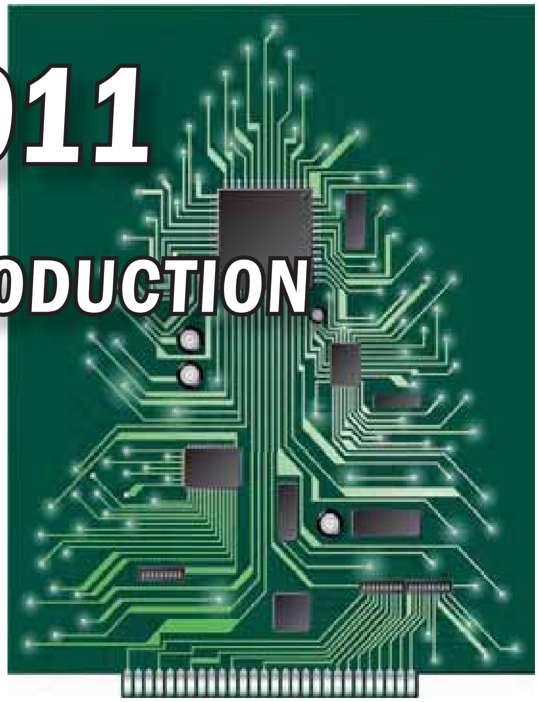
By this stage you should be having fun seeing just how sensitive the meter is. If adjusted correctly, you won't be able to gently exhale in the direction of the meter without an LED lighting-up, or LED voltage readings changing. Blowing at the device from two metres away will give an easily read change. But if you want to, some mechanical modifications can make the meter even more sensitive.

The first mod is to remove the protective mesh screens, front and back. Obviously, the internals of the meter are then more easily damaged – but the meter will be more sensitive.

The second mod is to install a tube that directs all air movement at just the central sensing part of the meter. To hold this in place, a plate can be mounted on one end of the airflow meter, with the tube glued through the centre of the plate. The tube can be plastic or even cardboard. *You must not touch the fragile platinum sensing wire – it's easily damaged.*

When an external sensing tube is added, the meter will easily detect the slowest exhalation you can make. Even when letting just a tiny amount of air flow from your mouth into the tube, the meter will display the change in airflow. Fitting a sensing tube like this allows even minute drafts around a house to be detected – eg, past a window frame. A flexible hose can be used instead of a solid tube, allowing airflows through electronic equipment to be checked and the meter to be used in other difficult-to-access places.

So there you have it – an extraordinary instrument that can be built just for fun or to perform serious measuring functions. ***EPE***



TEACH-IN 2011

A BROAD-BASED INTRODUCTION TO ELECTRONICS

Part 7: Timer circuits

By Mike and Richard Tooley

Our Teach-In series is designed to provide you with a broad-based introduction to electronics. We have attempted to provide coverage of three of the most important electronics units that are currently studied in many schools and colleges in the UK. These include Edexcel BTEC Level 2 awards, as well as electronics units of the new Diploma in Engineering (also at Level 2). The series will also provide the more experienced reader with an opportunity to 'brush up' on specific topics with which he or she may be less familiar.

Each part of our Teach-In series is organised under five main headings; Learn, Check, Build, Investigate and Amaze. Learn will teach you the theory, Check will help you to check your understanding, and Build will give you an opportunity to build and test simple electronic circuits. Investigate will provide you with a challenge which will allow you to further extend your learning, and finally, Amaze will show you the 'wow factor'!

IN THIS instalment of *Teach-In*, we will bring together several important ideas and concepts that we've already met in the earlier parts. At the same time, we will introduce you to a highly versatile integrated circuit (IC), the *555 timer*.

Using this IC, we will show you how you can quickly and easily design circuits that will produce time delays from a few hundred nanoseconds to several hundred seconds, and square wave pulses of known frequency, period and duty cycle. ***Build*** and ***Investigate*** will extend this further with a detailed look at some practical timer and pulse generator circuits. Finally, in ***Amaze*** we look at ways in which we measure time with a very high degree of accuracy.

Learn

The 555 timer

The 555 timer is, without doubt, one of the most versatile integrated circuit chips ever produced. Not only is it a neat mixture of analogue and digital circuitry, but its applications are virtually limitless in the world of digital pulse generation. The chip also makes an excellent case study for beginners because it brings together a number of important concepts and techniques. The standard 555 timer is supplied in a standard 8-pin dual-in-line (DIL) package with the pinout shown in Fig.7.1.

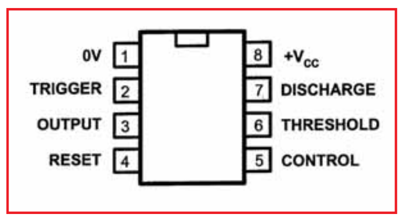


Fig.7.1. Pinout connections for a standard 555 timer IC

To begin to understand how timer circuits operate, it is worth spending a few moments studying the internal circuitry of the 555 timer, see Fig.7.2. Essentially, the chip comprises two operational amplifiers used as comparators, together with an R-S bistable. In addition, an inverting transistor amplifier is incorporated so that an appreciable current can be delivered to a load.

Sinking and sourcing

Unlike the standard logic devices that we met last month, the 555 timer can both *sink* and *source* current. It's worth taking a little time to explain what we mean by these two terms:

- When ***sourcing*** current, the 555's output (pin 3) is in the *high* state, and current will then flow *out* of the output pin into the load and down to 0V, as shown in Fig.7.3(a).
- When ***sinking*** current, the 555's output (pin 3) is in the *low* state, in which case current will flow from the positive supply ($+V_{CC}$) through the load and *into* the output (pin 3), as shown in Fig.7.3(b).

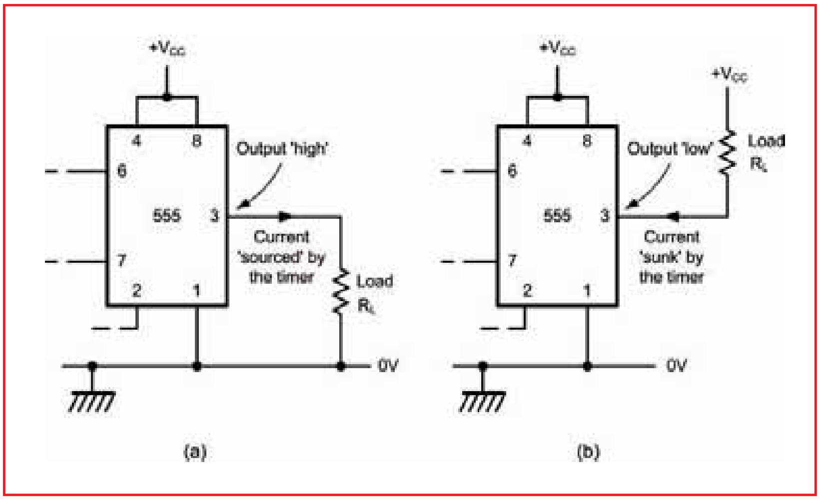


Fig.7.3. Loads connected to the output of a 555 timer: (a) current sourced by the timer when the output is high, (b) current sunk by the timer when the output is low

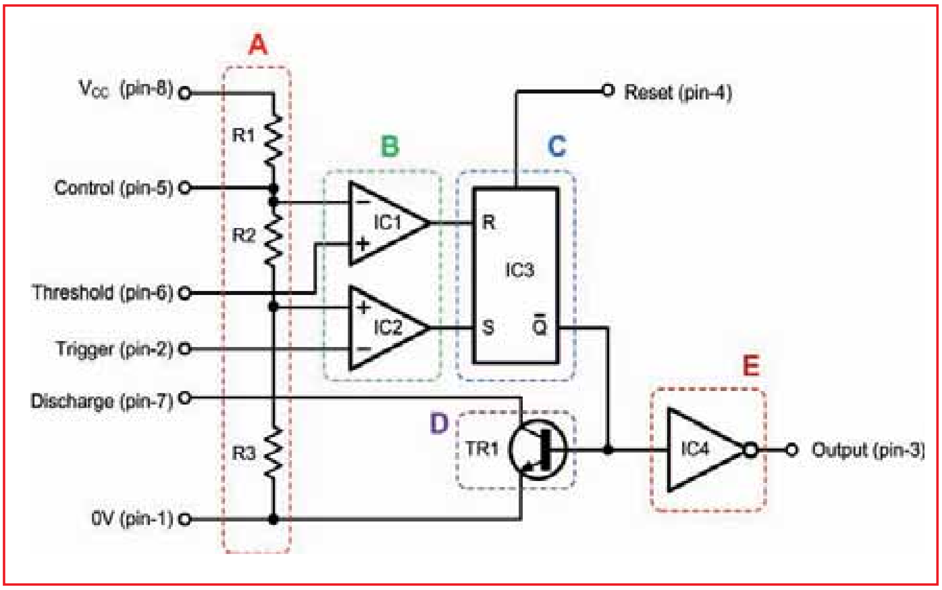


Fig.7.2. Internal schematic arrangement of the standard 555 timer

Table 7.1: Main features of the 555 timer IC

Feature	***Function***
A	A potential divider comprising R1, R2 and R3 connected in series. Since all three resistors have the same values the input voltage (V_{CC}) will be divided into thirds, i.e. one third of V_{CC} will appear at the junction of R2 and R3 while two thirds of V_{CC} will appear at the junction of R1 and R2.
B	Two operational amplifiers connected as comparators. The operational amplifiers are used to examine the voltages at the ***threshold*** and ***trigger*** inputs and compare these with the fixed voltages from the potential divider (two thirds and one third of V_{CC} respectively).
C	An R-S bistable stage. This stage can be either **set** or **reset** depending upon the output from the comparator stage. An external reset input is also provided.
D	An open-collector transistor switch. This stage is used to discharge an external capacitor by effectively shorting it out whenever the base of the transistor is driven positive.
E	An inverting power amplifier. This stage is capable of sourcing and sinking enough current (well over 100mA in the case of a standard 555 device) to drive a small relay or another low-resistance load connected to the output.

Returning to Fig.7.2, the single transistor switch, TR1, is provided as a means of rapidly discharging an external timing capacitor. Because the series chain of resistors, comprising R1, R2 and R3, all have identical values, the supply voltage (V_{CC}) is divided equally across the three resistors.

The voltage at the non-inverting input of IC1 is one-third of the supply voltage (V_{CC}), while that at the inverting input of IC2 is two-thirds of the supply voltage (V_{CC}). Thus, if V_{CC} is 9V, 3V will appear across each resistor and the upper comparator will have 6V applied to its inverting input, while the lower comparator will have 3V at its non-inverting input.

The 555 family

The standard 555 timer is housed in an 8-pin DIL package and operates from supply rail voltages of between 4.5V and 15V. This, of course, encompasses

the normal range for TTL devices (5V ±5%) and thus the device is ideally suited for use with TTL circuitry.

The following versions of the standard 555 timer are commonly available:

Low power 555

The low power 555 timer is a CMOS version that is both pin and function compatible with its standard counterpart. By virtue of its CMOS technology, the device operates over a somewhat wider range of supply voltages (2V to 18V) and consumes minimal operating current (120μA typical for an 18V supply).

Note that, by virtue of the low-power CMOS technology employed, the device does not have the same output current drive as that possessed by its standard counterparts. However, it can supply up to two standard TTL loads.

556 dual timer

The 556 is a dual version of the standard 555 timer housed in a 14-pin DIL package. The two devices may be used entirely independently and share the same electrical characteristics as the standard 555.

Low power 556

The low power 556 is a dual version of the low power CMOS 555 timer contained in a 14-pin DIL package. The two devices may again be used entirely independently and share the same electrical characteristics as the low power CMOS 555.

Please note!

Low power timers use CMOS technology and should be handled using anti-static precautions.

Monostable pulse generator

Fig. 7.4 shows a standard 555 timer operating as a ***monostable*** pulse generator. The term 'monostable' refers to the fact that the output has only one stable state, and it will always return to this state after a period of time spent in the opposite state. The monostable timing period (ie, the time for which the output is high) is initiated by a falling edge trigger pulse applied to the *trigger* input (pin 2).

When this falling edge trigger pulse is received and falls below one third of the supply voltage, the output of IC2 goes high and the bistable will be placed in the *set* state. The inverted Q output (ie, $\overline{Q}$) of the bistable then goes low, the internal transistor TR1 is placed in the off (non-conducting) state and the output voltage (pin 3) goes high.

The capacitor, C, then charges through the series resistor, R, until the voltage at the threshold input reaches two thirds of the supply voltage (V_{CC}). At this point, the output of the upper comparator changes state and the bistable is *reset*. The inverted Q output (ie, $\overline{Q}$) then goes high, TR1 is driven into conduction and the final output goes low. The device then remains in the inactive state until another falling trigger pulse is received.

Output waveform

The output waveform produced by the circuit of Fig.7.4 is shown in Fig.7.5. The waveform has the following properties:

Time for which output is high:

$$t_{on} = 1.1\ C\ R$$

Recommended trigger pulse width:

$$t_{tr} < \frac{t_{on}}{4}$$

Where t_{on} and t_{tr} are in seconds, *C* is in farads and *R* is in ohms.

The period of the 555 monostable output can be changed very easily by simply altering the values of the timing resistor, *R*, and/or timing capacitor, *C*. Doubling the value of *R* will double the timing period. Similarly, doubling the value of *C* will double the timing period.

Please note!

The usual range of values for capacitance and resistance in a monostable timer are 470pF to 470μF and 1kΩ to 3.3MΩ respectively. Outside this range operation is less predictable.

Example 1

Now let's work through a simple design example. For this we shall

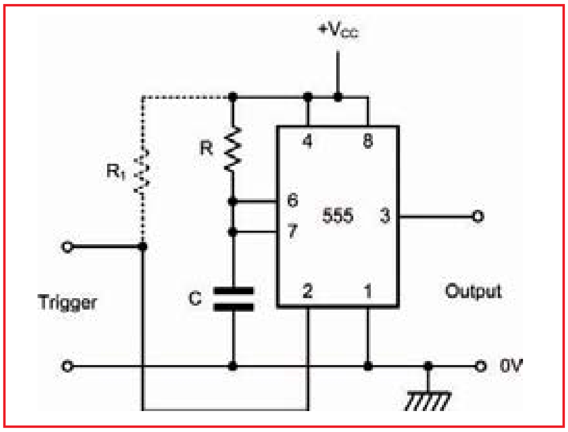


Fig.7.4. A 555 timer in monostable configuration

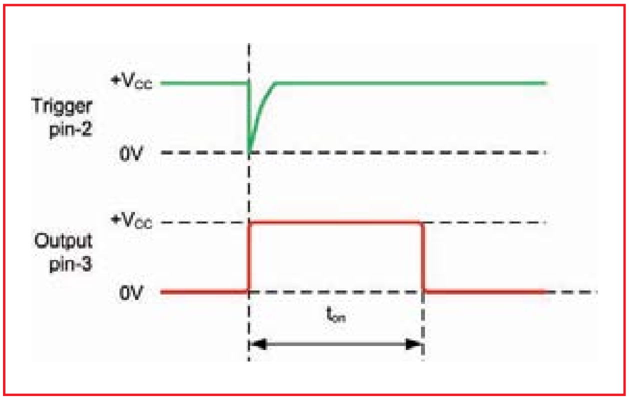
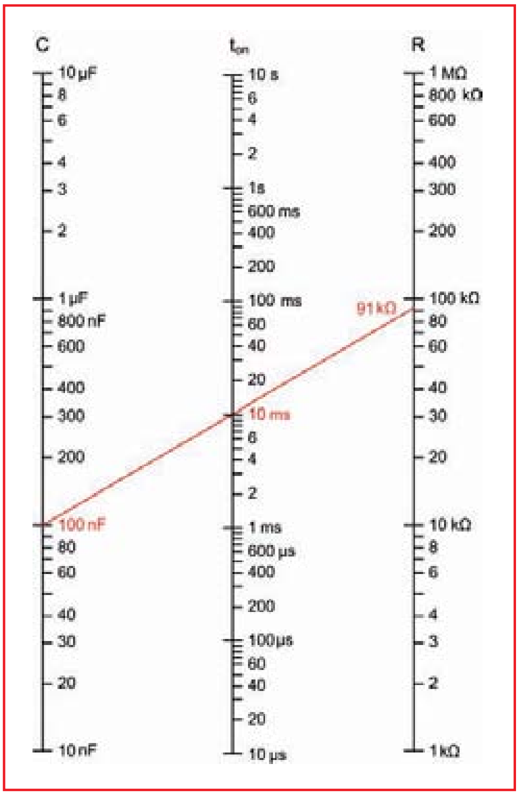


Fig.7.5. Waveforms for monostable operation



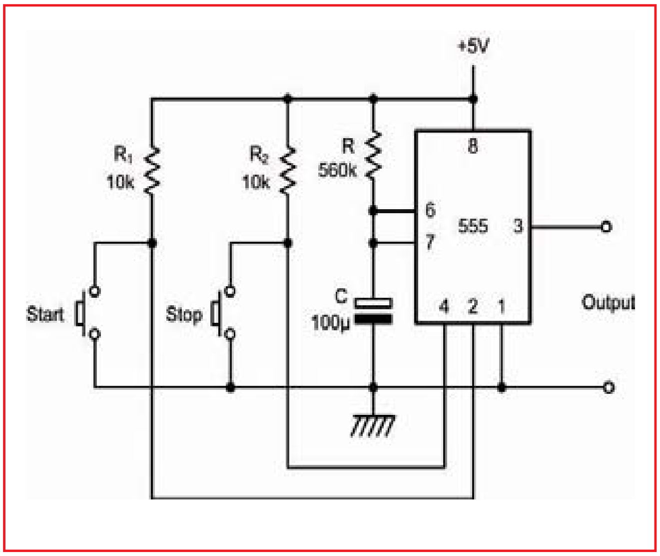


Fig.7.7 (above). Circuit diagram for a 60 second timer (see Example 2)

Fig.7.6. (left) Graph for determining values of C, t_{on} and R for a 555 operating in monostable mode. The red line shows how a 10ms pulse will be produced when C = 100nF and R = 91kΩ (see Example 1)

assume that we need a circuit that will produce a 10ms pulse when a negative-going trigger pulse is applied to it. Using the circuit shown in Fig. 7.4, the value of monostable timing period can be calculated from the formula:

$$t_{on} = 1.1\ C\ R$$

We need to choose an appropriate value for C that is in the range stated earlier. Since we require a fairly modest time period, we will choose a mid-range value for C.

This should help to ensure that the value of R is neither too small nor too large. A value of 100nF should be appropriate and should also be easy to obtain. Making R the subject of the formula and substituting for C = 100nF gives:

$$R = \frac{t_{on}}{1.1C} = \frac{10\text{ms}}{1.1\times 100\text{nF}} = \frac{10\times 10^{-3}}{110\times 10^{-9}}$$

From which:

$$R = \frac{10}{110}\times 10^{6} = 0.091\times 10^{6}\ \Omega$$

$$\text{or}\ \ 91\,\text{k}\Omega$$

Alternatively, the graph shown in Fig.7.6 can be used.

Example 2

Next, we shall design a timer circuit that will produce a +5V output for a period of 60s when a 'start' button is operated. The time period is to be aborted when a 'stop' button is operated. For the purposes of this example we shall assume that the 'start' and 'stop' buttons both have normally-open (NO) actions. The value of monostable timing period can be calculated from the formula:

$$t_{on} = 1.1\ C\ R$$

We need to choose an appropriate value for C that is in the range stated earlier. Since we require a fairly long time period we will choose a relatively large value of C in order to avoid making the value of R too high.

A value of 100µF should be appropriate and should also be easy to obtain. Making R the subject of the formula, and substituting for C = 100µF gives:

$$R = \frac{t_{on}}{1.1C} = \frac{60\text{s}}{1.1\times 100\mu\text{F}} = \frac{60}{110\times 10^{-6}}$$

60

From which:

$$R = \frac{60}{110}\times 10^{6} = 0.545\times 10^{6}\ \Omega$$

$$\text{or}\ \ 545\,\text{k}\Omega$$

In practice 560kΩ (the nearest preferred value) would be adequate.

The 'start' button needs to be connected between pin 2 and ground, while the 'stop' button needs to be connected between pin 4 and ground. Each of the inputs requires

a 'pull-up' resistor to ensure that the input is taken high when the switch is not being operated.

The precise value of the 'pull-up' resistor is unimportant, and a value of 10kΩ will be perfectly adequate in this application. The complete circuit of the 60s timer is shown in Fig.7.7.

Astable pulse generator

How the standard 555 can be configured as an ***astable*** pulse generator, is shown in Fig.7.8. In order to understand how this circuit operates, assume that the output (pin 3) is initially high and that TR1 is in the non-conducting state. The capacitor, C, will begin to charge with current supplied by series resistors, R_1 and R_2.

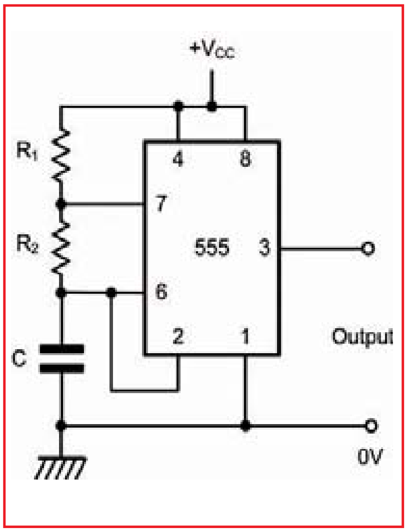


Fig.7.8. 555 astable configuration

When the voltage at the *threshold* input (pin 6) exceeds two thirds of the supply voltage, the output of the upper comparator, IC1, will change state and the bistable will become *reset*, due to the voltage transition that appears at R. This, in turn, will make the $\overline{Q}$ output go high, turning TR1 on and saturating it at the same time. Due to the inverting action of the buffer (IC4, see Fig.7.2), the final output (pin 3) will go low.

The capacitor, C, will now discharge, with current flowing through R2 into the collector of TR1. At a certain point, the voltage appearing at the *trigger* input (pin 2) will have fallen back to one third of the supply voltage, at which point the lower comparator will change state and the voltage transition at S (Fig.7.2) will return the bistable to its original *set* condition. The inverted $\overline{Q}$ output then goes low, TR1 switches off (no longer conducting), and the output (pin 3) goes high. Thereafter, the entire charge/discharge cycle is repeated indefinitely.

The output waveform produced by the circuit of Fig.7.8 is shown in Fig.7.9. The waveform has the following properties:

Time for which output is high:

$$t_{on} = 0.693\ C\ (R_1 + R_2)$$

Time for which output is low:

$$t_{off} = 0.693\ C\ R_2$$

Period of output waveform:

$$t = t_{on} + t_{off} = 0.693\ C\ (R_1 + 2R_2)$$

Pulse repetition frequency:

$$\text{p.r.f.} = \frac{1.44}{C(R_1+2R_2)}$$

Mark-to-space ratio:

$$\frac{t_{on}}{t_{off}} = \frac{R_1+R_2}{R_2}$$

Duty cycle:

$$\frac{t_{on}}{t_{on}+t_{off}} = \frac{R_1+R_2}{R_1+2R_2} \times 100\%$$

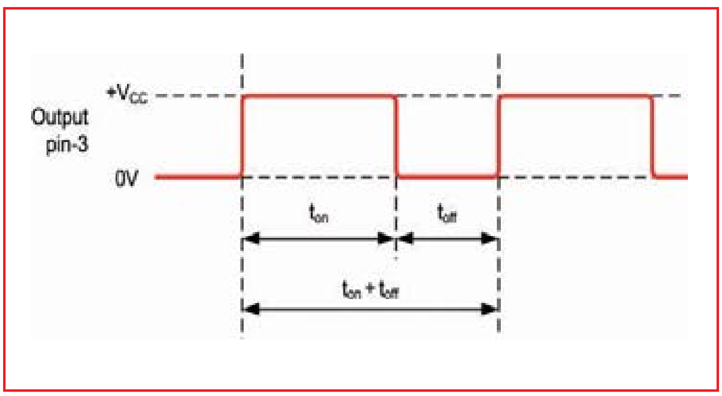


Fig.7.9. Waveforms for astable operation

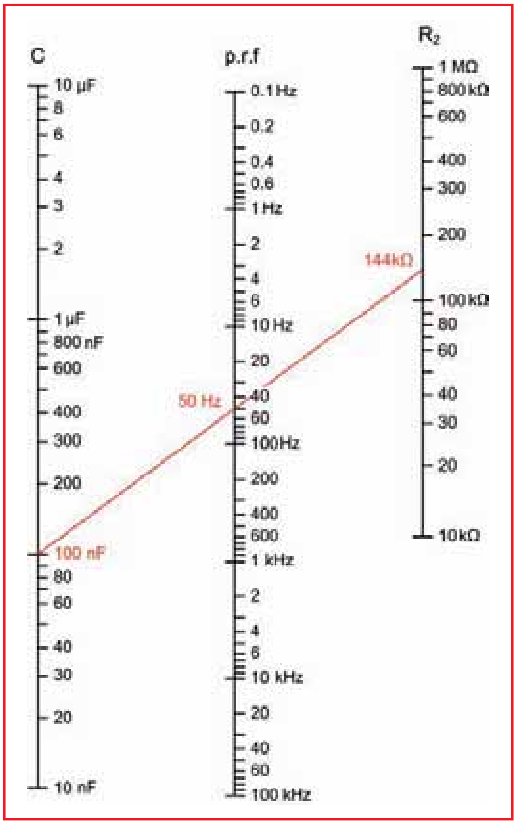


Fig.7.10. Graph for determining values of C, p.r.f, and R_2 for a 555 operating in astable mode where R_2 >> R_1 (ie, for square wave operation). The red line shows how a 50Hz square wave will be produced when C = 100nF and R = 144kΩ (see Example 4)

Where t is in seconds, C is in farads, R_1 and R_2 are in ohms.

When $R_1 = R_2$, the duty cycle of the astable output from the timer can be found by letting $R = R_1 = R_2$. In this condition:

$$\frac{t_{on}}{t_{off}} = \frac{R_1 + R_2}{R_2} = \frac{R + R}{R} = \frac{2}{1} = 2$$

In this case, the duty cycle will be given by:

$$\frac{t_{on}}{t_{on} + t_{off}} = \frac{R_1 + R_2}{R_1 + 2R_2} \times 100\%$$

$$= \frac{R + R}{R + 2R} \times 100\%$$

Thus:

$$\frac{t_{on}}{t_{on} + t_{off}} = \frac{2R}{3R} \times 100\%$$

$$= \frac{2}{3} \times 100\% = 67\%$$

The p.r.f. of the 555 astable output can be changed very easily by simply altering the values of R_1, R_2, and C. The required values of C, R_1 and R_2 for any required p.r.f. and duty cycle can be determined from the formulae shown earlier. Alternatively, the graph shown in Fig.7.10 can be used when R_1 and R_2 are equal in value (corresponding to a 67% duty cycle).

Please note!

The usual range of values for capacitance and resistance in an astable timer are 10nF to 470μF for C, and 1kΩ to 1MΩ for R_1 and R_2. As for the monostable circuit, operation is less predictable outside this range.

Square wave generators

Because the high time (t_{on}) is always greater than the low time (t_{off}), the mark-to-space ratio produced by a 555 timer can never be made equal to (or less than) unity. This could be a problem if we need to produce a precise square wave in which $t_{on} = t_{off}$.

However, by making R_2 very much larger than R_1, the timer can be made to produce a reasonably symmetrical square wave output. (Note, that the minimum recommended value for R_2 is 1kΩ – see *Please note!*).

If $R_2 >> R_1$, the expressions for p.r.f. and duty cycle simplify to:

$$\text{p.r.f.} = \frac{0.72}{CR_2}$$

$$\frac{t_{on}}{t_{on} + t_{off}} = \frac{R_2}{2R_2} \times 100\%$$

$$= \frac{1}{2} \times 100\% = 50\%$$

Example 3

Let's design a pulse generator that will produce a p.r.f. of 10Hz with a 67% duty cycle (ie, the output will be high for one third of the time and low for two thirds of the time).

Using the circuit that we met in Fig.7.8, the value of p.r.f. can be calculated from:

$$\text{p.r.f.} = \frac{1.44}{C(R_1 + 2R_2)}$$

Since the specified duty cycle is 67%, we can make R_1 equal to R_2. Hence, if $R = R_1 = R_2$ we obtain the following relationship:

$$\text{p.r.f.} = \frac{1.44}{C(R + 2R)} = \frac{1.44}{3CR} = \frac{0.48}{CR}$$

We need to choose an appropriate value for C that is in the range stated earlier. Since we require a fairly low value of p.r.f., we will choose a value for C of 1μF. This should help to ensure that the value of R is neither too small nor too large. A value of 1μF should also be easy to obtain. Making R the subject of the formula, and substituting for C = 1μF gives:

$$R = \frac{0.48}{\text{p.r.f.} \times C}$$

$$= \frac{0.48}{\text{p.r.f.} \times 1 \times 10^{-6}}$$

Hence:

$$R = \frac{480 \times 10^3}{10} = 4.8 \times 10^4 = 48\text{k}\Omega$$

Example 4

Now let's design a 5V 50Hz square wave generator using a 555 timer.

Using the circuit shown in Fig.7.11, when $R_2 >> R_1$, the value of p.r.f. can be calculated from:

$$\text{p.r.f.} = \frac{0.72}{CR_2}$$

We shall use the minimum recommended value for R_1 (ie, 10kΩ) and ensure that the value of R2 that we calculate from the formula is at least ten times larger, in order to satisfy the criteria that R_2 should be very much larger than R_1.

When selecting the value for C, we need to choose a value that will keep the value of R_2 relatively

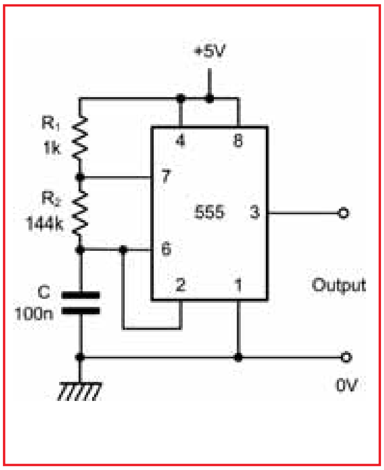


Fig.7.11. Circuit for a 5V 50Hz square wave genrator (see Example 4)

large. A value of 100nF should be about right, and should also be easy to locate. Making R_2 the subject of the formula and substituting for C = 100nF gives:

$$R_2 = \frac{0.72}{\text{p.r.f.} \times C} = \frac{0.72}{50 \times 100 \times 10^{-9}}$$

$$= \frac{0.72}{5 \times 10^{-6}}$$

Hence:

$$R_2 = \frac{0.72 \times 10^{6}}{5}$$

$$= 0.144 \times 10^{6} = 144\,\text{k}\Omega$$

Alternatively, the graph shown in Fig.7.10 can be used.

The value of R_2 is more than 100 times larger than the value that we are using for R_1. As a consequence, the timer should produce a good square wave output. The complete circuit of our 5V 50Hz square wave generator is shown in Fig.7.11.

Check – How do you think you are doing?

7.1. Explain the difference between monostable and astable timer operation.

7.2. Sketch the circuit of a monostable timer and identify the components that determine the time for which the output is high.

7.3. Sketch the circuit of an astable pulse generator and identify the components that determine the time for which (a) the output is high, and (b) the output is low.

7.4. Design a timer circuit that will produce a 6V 20ms pulse when a 6V negative-going trigger pulse is applied to it.

7.5. Design a timer circuit that will produce a 67% duty cycle output at 250Hz.

7.6. A 555 timer is rated for a maximum output current of 120mA. What is the minimum value of load resistance that can be used if the device is to be operated from a 6V DC supply?

For more information, links and other resources please check out our Teach-In website at:
www.tooley.co.uk/teach-in

Build – The Circuit Wizard way

Kitchen timer

OUR first practical circuit uses the 555 timer configured as a monostable to operate as a kitchen timer, as shown in Fig.7.12. When SW1 is closed the buzzer will sound until SW2 is pressed to start the timer. The two probes help us to see the charge building in C1 and the status of the output. A sample trace is shown in Fig.7.13. This is particularly useful for testing long delays where the circuit may seem to being inactive.

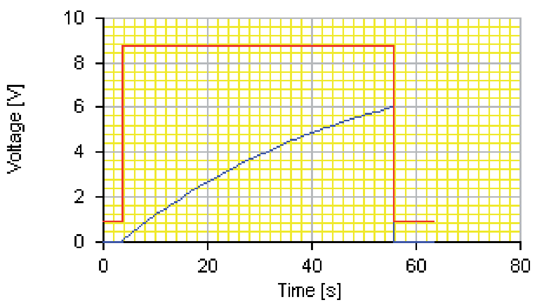


Fig.7.13. Sample trace for the kitchen timer circuit

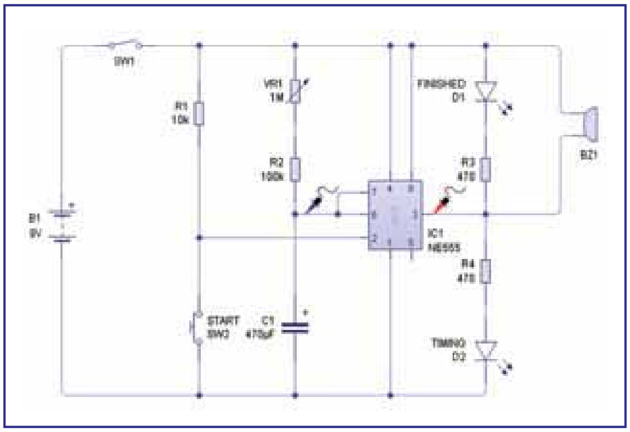


Fig.7.12. Kitchen timer using a 555 in a monostable configuration

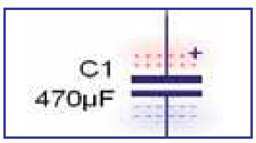


Fig.7.14. Charge building on C1 in 'Voltage Levels' view

Similarly, in 'Voltage Levels' or 'Current Flow' we are able to visualise the charge building on the capacitor as a series of '+' and '-' appear on the plates (see Fig.7.14).

The amount of elapsed time before the buzzer activates can be altered by changing the value of pot VR1. Experiment with running the timer for various settings of VR1 to ascertain the minimum/maximum times, then confirm this using the appropriate formulae that was introduced in 'Learn' (you may have to be very patient for the maximum delay!).

A soft boiled egg is cooked for four minutes (240 seconds) – calculate the value required for VR1, then set this on your circuit and check out your theory in practice.

LED flasher

In our second circuit (see Fig.7.15), we utilise the 555 in an astable configuration to generate alternate flashing lights. Typical example applications might include children's toys, signs, alarm systems, and level crossings. Varying the value of VR1 will alter the frequency of the flashing.

Circuit Wizard's 'Current View' comes in to its own here for visualising the continuously changing state of the circuit, as shown in Fig.7.16. Apart from looking like a 70s disco, the colours clearly show how current is sinking and sourcing though the output (pin 3) as each of the LEDs is lit. You can also monitor how the capacitor charges until the threshold voltage is reached, and is then discharged through pin 7.

As with the first circuit, the probes and trace (Fig.7.16) also help us to understand the inputs and outputs. The blue probe/line showing the voltage to pin 2 and pin 6, and the red line showing the output (pin 3).

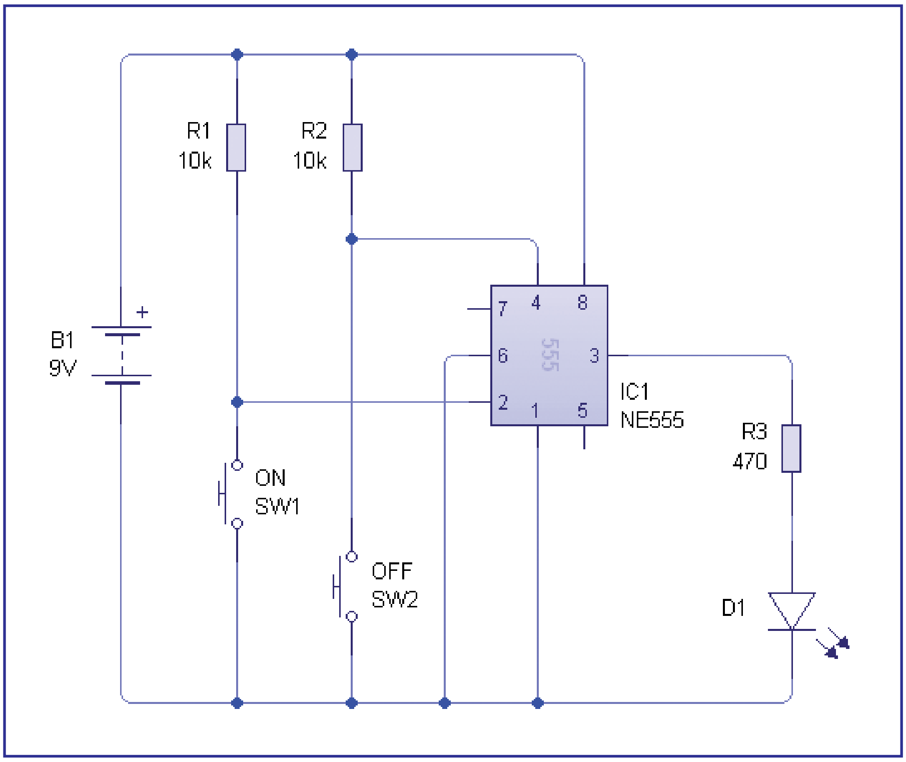


Fig.7.17. A simple 555 bistable 'on-off' circuit

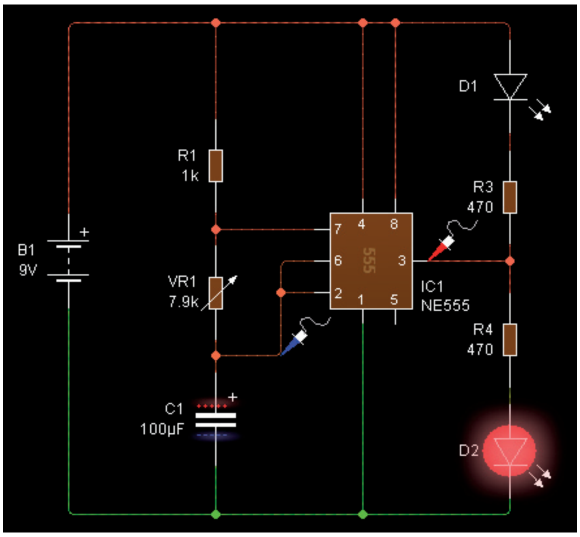


Fig.7.15. A 555 astable alternate LED flasher circuit (shown in Current View)

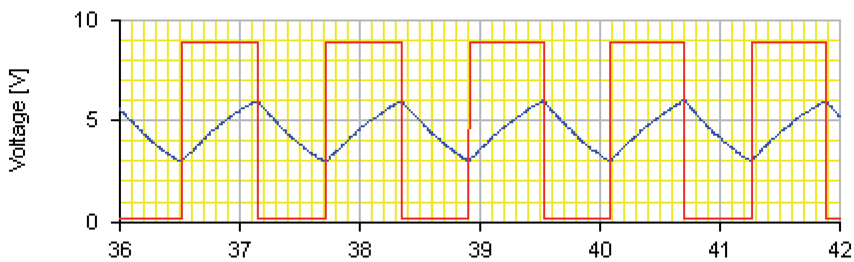


Fig.7.16. Trace for 555 alternate LED flasher circuit

On-Off circuit

As well as using the 555 as a timer in monostable mode, it can also be used as a bistable. A neat application of this is a simple 'on-off' circuit, where SW1 is pressed to turn on or 'set' the output and SW2 is pressed to 'reset' or turn off the output (see Fig.7.17).

A further application of this might be a signalling circuit, where SW1 is pressed to 'set green' and SW2 is pressed to 'set red', as shown in Fig.7.18.

Decade counter

In Part 6 (*Logic Circuits*), we constructed a decade (ie, 0 to 9)

The Circuit Wizard way

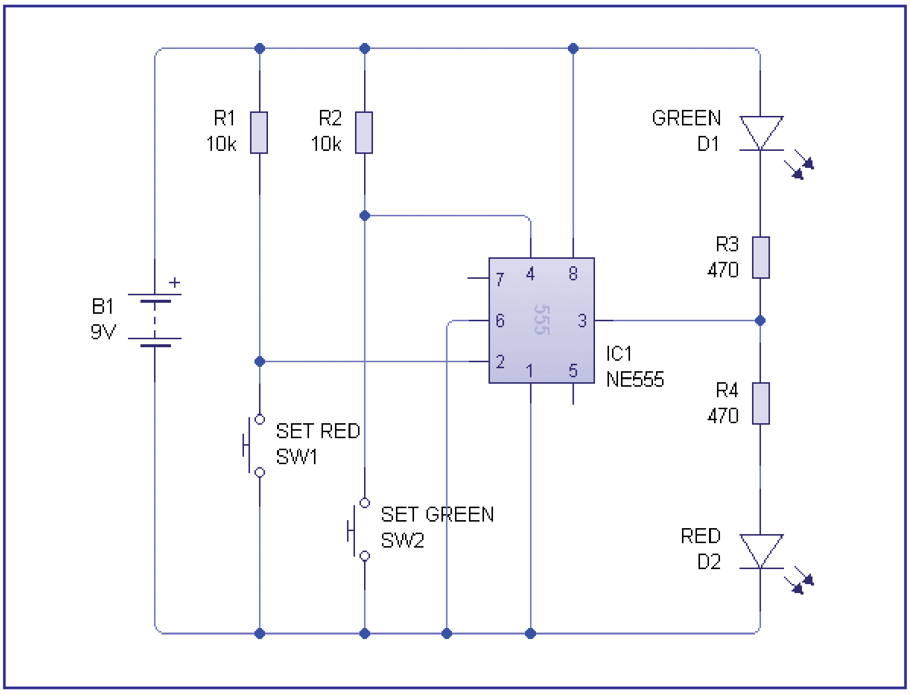


Fig.7.18 A 555 red/green signal circuit

counter circuit using a 4-bit ripple counter followed by a seven-segment driver and display. We used Circuit Wizard's built in clock to test the circuit.

However, in real life we would need circuitry to create this clock. One way of doing this would be to use a 555 configured in astable mode. Try out the circuit shown in Fig. 7.19 (if you have your 0-9 counter circuit saved from Part 6 you could amend it to include the additional components).

Dual timers

In some circuits we may want to use more than one timer. The 556 IC effectively contains two 555s in one physical package. Our last circuit uses two timers 'daisy-chained' together to create a sequence of four flashes followed by a gap.

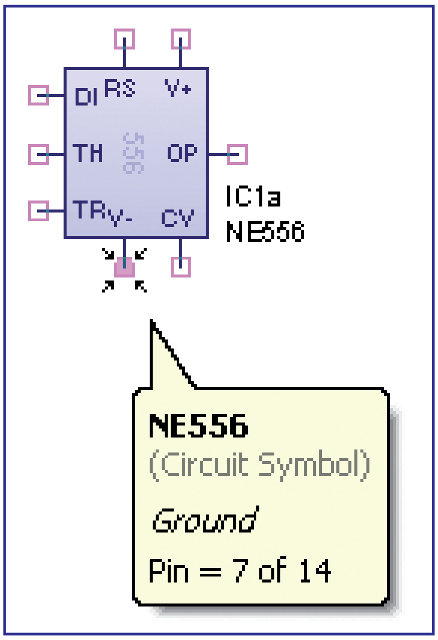
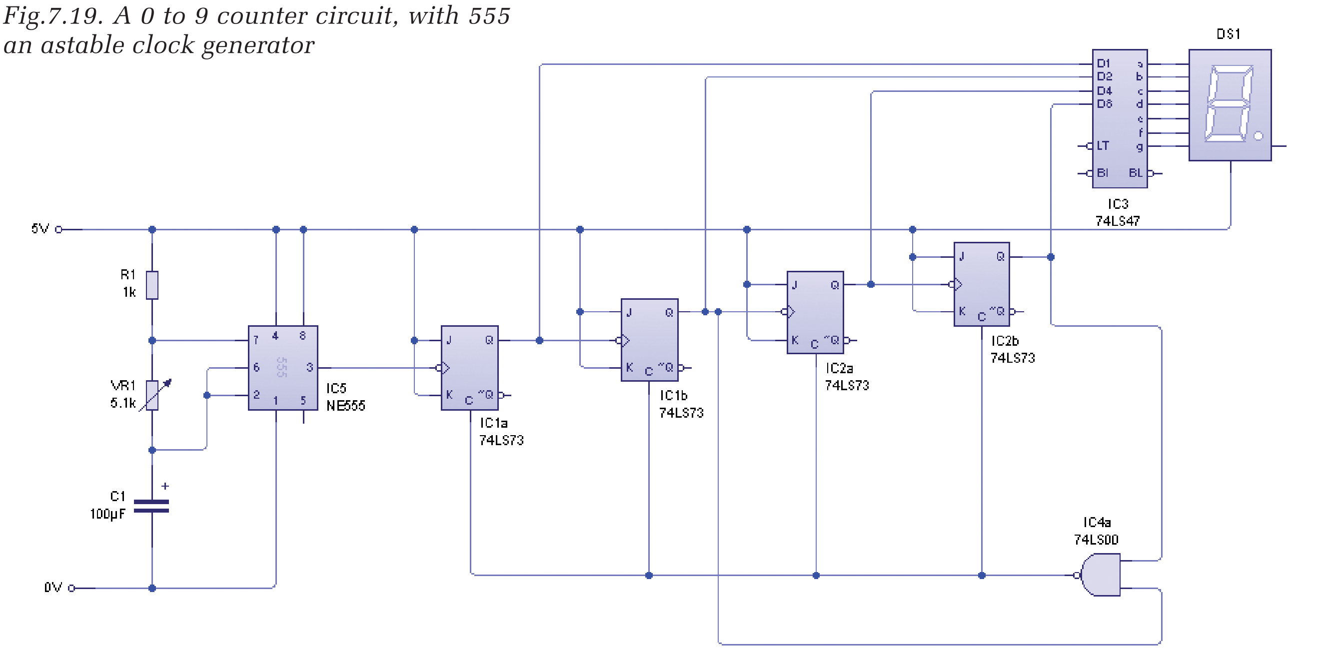


Fig.7.20. Tooltip showing pin description and number

Fig.7.19. A 0 to 9 counter circuit, with 555 an astable clock generator



To use both timers contained within the 556 in Circuit Wizard, you need to drag two separate instances of the 556 on to the circuit page. The first timer will be suffixed 'a' and the second 'b' (eg, IC1a and IC1b). As both are contained within one physical package, this would be reflected when converting to a PCB for example.

Unlike the 555 symbol that has numbered pins, Circuit Wizard labels the pins of the 556 verbosely; for example, the threshold input is labelled 'TH'. As with any integrated circuit, by hovering over the pin you are able to see the physical pin location in the tooltip (see Fig.7.20).

Construct the circuit shown in Fig.7.21 and observe its operation. Both timers are configured in astable mode. The first timer (IC1a) has a frequency of about 0.5Hz. The output from this timer is then used to supply the second timer (IC1b) which has a frequency of about 2Hz.

During the period when the output of timer one is high, the second timer will be activated and oscillate four times, hence giving four flashes. Conversely, when the output of the first timer is low, the second timer is not powered and so the output LED remains unlit. Try experimenting with the circuit, perhaps changing the sequence to give only two flashes by changing the relative frequencies of each timer.

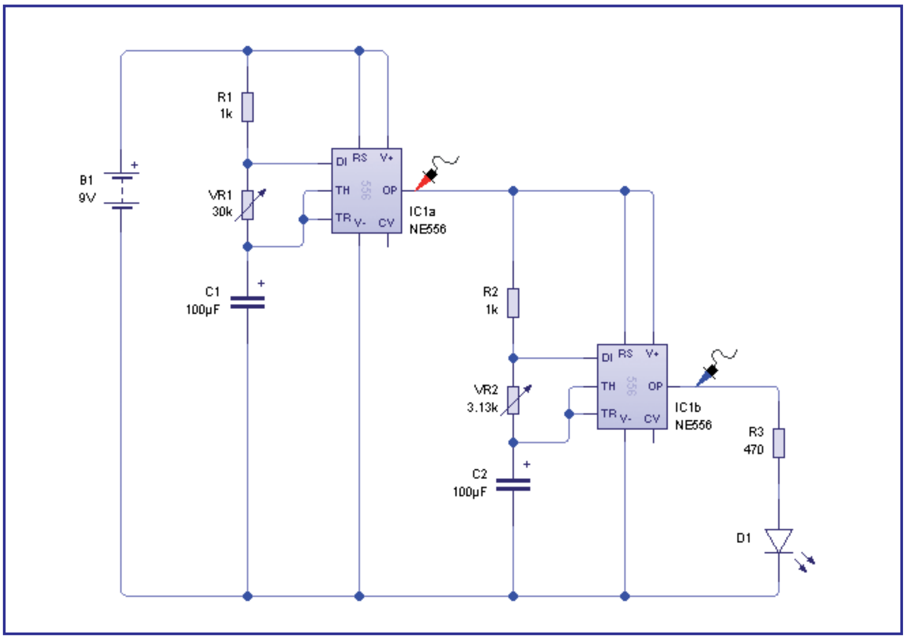


Fig.7.21. A 556 flasher sequence circuit

Note that during the first 'high' of each cycle (both for IC1a and IC1b) the duration of energised output will be slightly longer. This is because C1 and C2 start to charge from 0V on the initial charge, rather than 1/3rd of the supply voltage on subsequent charges.

This can be seen clearly on the trace below, where the red line indicates the output of timer one (IC1a) and the blue line, timer two (IC1b). This has the effect that on the *initial* sequence *only*, the LED will flash seven times rather than four! Can you design a circuit using your knowledge from previous parts of *Teach-In* to produce the same sequence, but without the same issues?

Circuit Wizard

A *Standard* or *Professional* version of Circuit Wizard can be purchased from the editorial office of *EPE* – see *CD-ROMs for Electronics* page and the UK shop on our website (**www.epemag.com**).

Further information can be found on the New Wave Concepts website; **www.new-wave-concepts.com**. The developer also offers an evaluation copy of the software that will operate for 30 days, although it does have some limitations applied, such as only being able to simulate the included sample circuits and no ability to save your creations.

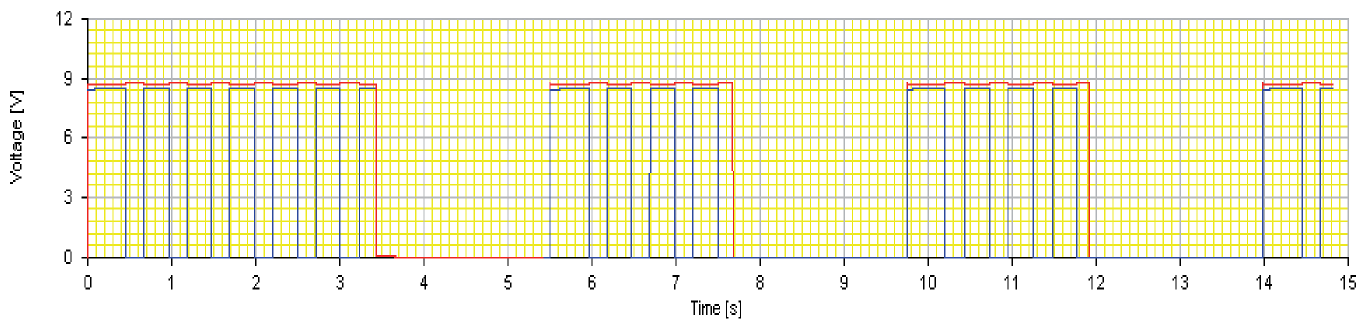


Fig.7.22. A 556 flasher sequence circuit trace

Investigate

The complete circuit diagram of a variable pulse generator is shown in Fig.7.23. Look at this circuit carefully and then answer the following questions:

1. Identify the component or components that:

(a) determine the pulse repetition frequency

(b) provide variable adjustment of the pulse width

(c) provide variable adjustment of the output amplitude

(d) limit the range of variable adjustment of pulse width

(e) protect IC2 against a short-circuit connected at the output

(f) remove any unwanted signals appearing on the supply rail

(g) form the trigger pulse required by the monostable stage.

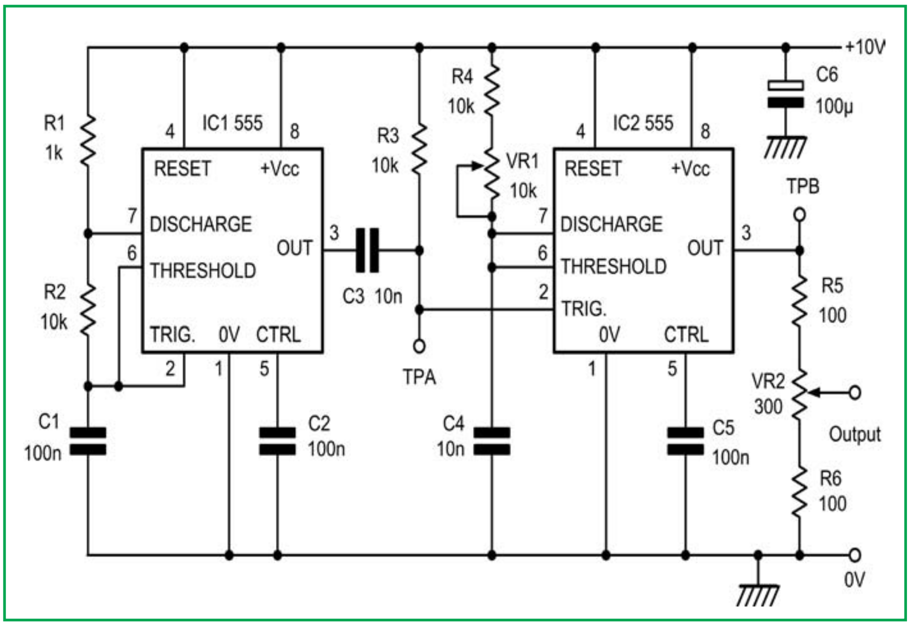


Fig.7.23. Practical circuit diagram for a variable pulse generator

2. Sketch waveforms to a common time scale showing the signals at (a) TPA and (b) TPB 'test points'.

3. Determine the pulse repetition frequency of the output.

4. Determine the maximum and minimum pulse width of the output.

5. Determine the maximum and minimum amplitude of the output.

Amaze

In last month's *Amaze* we described significant advances in the speed at which digital logic can operate. This month, we will be looking at the way in which we accurately measure time:

Simple audible and visible signals were once used to inform people about the passing of time and as a means of setting their own clocks. For example, a canon could be fired at precisely one o'clock every day. However, with the advent of telegraph, telephone and radio in the 20th century, time signals could be broadcast internationally and made accessible to anyone that needed them.

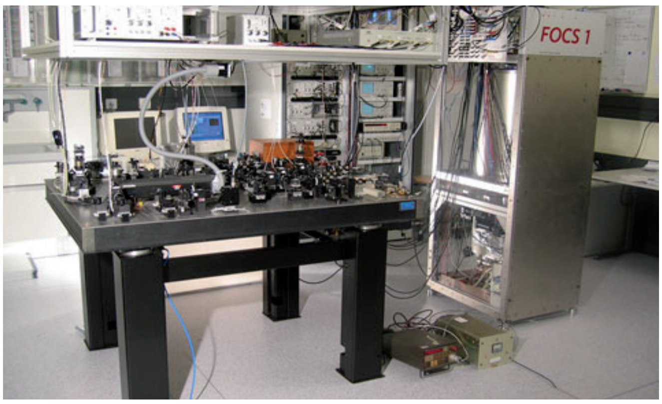


Fig.7.24. FOCS-1, a continuous cold caesium fountain atomic clock in Switzerland. The clock started operating in 2004 and keeps time to an accuracy of one second in 30 million years

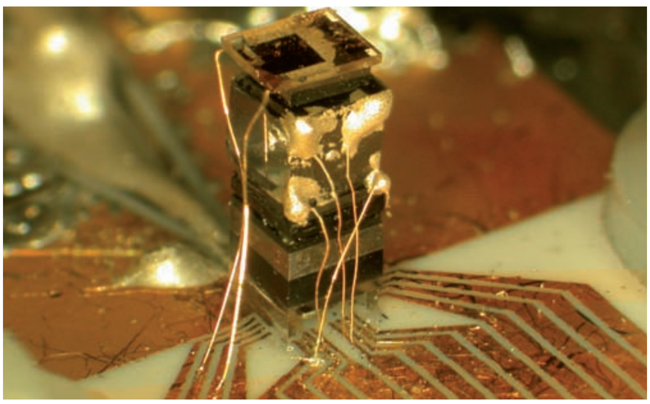


Fig.7.25. Atomic clocks are usually large and cumbersome devices, but much effort has been directed in making them small enough to be carried around. This is NIST's recently developed chip-scale atomic clock

Since time is the reciprocal of frequency, a time standard can be easily derived from an accurate frequency standard or 'clock'. All you need to do is count the number of cycles generated by the clock and, as long as the frequency is accurately known, the number of cycles will be an accurate measure of time. Today's off-air broadcast time signals use oscillators that are locked to atomic clocks.

Atomic clocks

The first atomic clock used the vibrations of ammonia molecules and was invented over sixty years ago. Atomic clocks use the vibrations of atoms or molecules, but because the frequency of these oscillations is so high, it is not possible to use them as a direct means of controlling a clock. Instead, the clock is controlled by a highly stable crystal oscillator whose output is automatically multiplied and compared with the frequency of the atomic system.

If two atomic clocks are compared there is always the possibility of a difference in their readings. This 'uncertainty' is the difference in indicated time if both were started at the same instant and later compared. For the early atomic clocks, this lack of certainty was estimated to be around one second in three thousand years.

Modern atomic clocks are based on caesium and rubidium, and they offer uncertainties of better than one second in 20 million years. But, if that's not good enough for you to set your watch by, the latest generation of quantum logic clocks, developed in 2008 at the National Institute of Standards and Technology (NIST) in the USA, offer an uncertainty of better than one second in over a billion years!

Answers to Check questions

7.1. See pages 46 and 48

7.2. See Fig.7.4 and associated text

7.3. See Fig.7.8 and associated text

7.4. See Fig.7.4 with R = 182kΩ and C =100nF and operating from a 6V DC supply

7.5. See Fig.7.8 with R_1 = 19.2kΩ, R_2 = 19.2kΩ and C = 100nF

7.6. 50Ω.

Next month!

In next month's Teach-In, we will be looking at some applications of analogue circuits, including filters and attenuators.

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Feedback continued

LAST month we started looking at a question from forum contributor ***Lost*** concerning collector-base feedback for a single-transistor amplifier.

Consider a capacitor-coupled NPN *transistor amplifier with collector-base bias. Assume that the reactance of the capacitor is negligible at signal frequencies.*

What type of feedback is involved – series-voltage, series-current, shunt-voltage or shunt-current? What is the feedback equation for this stage? ... Neither does it obey the standard negative feedback equation. That's why I asked if anyone knows what equation this 'simple' circuit follows.

Feedback amplifier

The circuit for a feedback amplifier of this type is shown in Fig.1. Last month we looked at some basic feedback theory using the generalised structure of a feedback amplifier shown in Fig.2. This leads to the well know 'standard' feedback equation to which Lost refers:

$$A_{CL} = \frac{A}{(1+\beta A)}$$

This equation relates the closed-loop gain (of the whole circuit), A_{CL}, to the open-loop gain of the amplifier itself, *A*, and proportion of the output fed back to the input, β. We also saw how for very large values of *A* and moderate β we can make the approximation:

$$A_{CL} = \frac{1}{\beta}$$

The amplifier structure in Fig.2 is applicable with either voltage or current signals at both input and output. This leads us to consider four types of amplifier: *voltage*, *current*, *transconductance* and *transresistance*; and to four corresponding types of feedback *series-voltage*, *shunt current*, *series current* and *shunt-voltage*.

We can easily apply this feedback theory to the standard op amp non-inverting amplifier circuit (Fig.3) – the feedback is applied via the potential divider network formed by R_1 and R_2, to the amplifier's inverting input. So $\beta = R_2/(R_1+R_2)$, which using $A_{CL} = 1/\beta$ gives the well-known expression for the gain of this amplifier:

$$A_{CL} = 1 + \frac{R_1}{R_2}$$

The mixing network shown in Fig.2 is provided by the differential nature of the op amp's input, so the mixer does not really exist as a separate entity from the amplifier in the actual circuit. It is important to remember that Fig.2 is an abstract representation of the signal relationships, not a block schematic of the actual amplifier circuit.

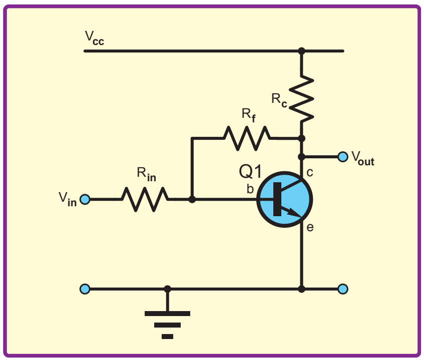


Fig.1. Transistor amplifier with feedback

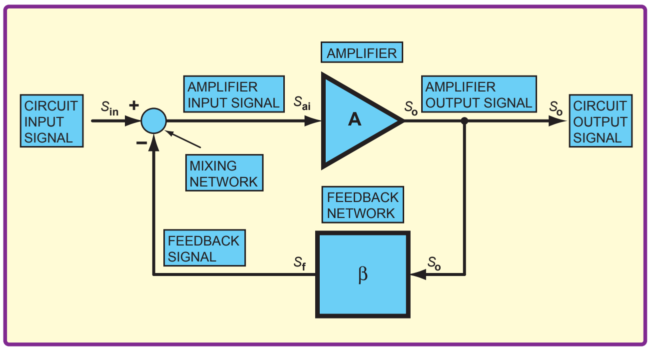


Fig.2. Structure of a feedback amplifier circuit

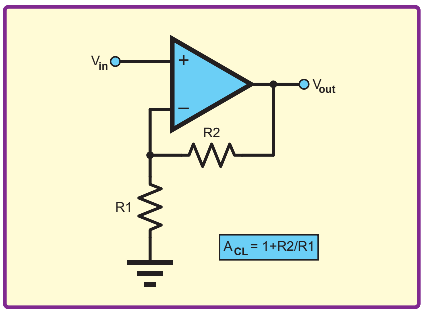


Fig.3. Op amp non-inverting amplifier

We might expect that it would be equally straightforward to apply Fig.2 and the associated feedback equation to the inverting op amp amplifier (Fig.4), but it is a little more complicated than the non-inverting case. However, it is worth investigating because it turns out that if we assume the transistor and collector resistor, R_C, in Fig.1 form a perfect voltage amplifier the whole circuit is equivalent to Fig.4 (with an ideal op amp). This is illustrated in Fig.5 where the schematic of Fig.1 has been redrawn to show how Fig.1 corresponds to Fig.4.

Feedback analysis

We can analyse the feedback in the circuit in Fig.4 and Fig.5 in more than one way; we will look at two approaches.

For simplicity, we will refer to the op amp in Fig.4, but our discussion could also apply to the combination of Q1 and R_C depicted in Fig.5. In this analysis we will assume the amplifier is ideal, that is it has voltage gain approaching infinity, infinite input impedance, zero output impedance and produces no noise or other imperfections.

We may question the usefulness of idealising the circuit in this way. After all, although the best op amps may deliver very good performance in terms of high gain and input impedance, the single transistor is unlikely to come very close.

However, this is still worth doing because an idealised analysis can give us insights into the fundamental principles of circuit operation. It can also provide a good starting point for analysing the impact imperfections and realistic parameters will have on circuit performance.

Transresistance amplifier

For the first analysis, we will regard the op amp and R_f as a transresistance amplifier. Our original schematic has a voltage input, but we can regard this as

being converted, to an input current by R_{in}. As our op amp has very high gain, the inverting input must be at a very low voltage. If this was not true the output voltages would be unrealistically large; or looked at another way, the op amp would be saturated and no longer acting as a linear amplifier.

Some numbers may help with the appreciation of this idea. If we assume a supply voltage of ±5V and an op amp gain of one million then the voltage at the inverting input will be no more than 5μV during normal operation. If we assume a gain of, say, 10 for the whole circuit (Fig.4) then the input voltage will be no more than 5V/10 = 0.5V for maximum output. The voltage across R_{in} will be around 5μV less than 0.5V; but 0.5V is so much larger than 5μV we can safely ignore the 5μV.

If we have an ideal op amp, then the gain will be much larger than one million, so the voltage at the inverting input will tend towards zero, and the voltage across R_{in} will be exactly equal to V_{in}. This means that input current to the transresistance version of our circuit is simply V_{in}/R_{in}. We can redraw the circuit as shown in Fig.6.

Shunt-voltage feedback

The feedback in Fig.6 is driven by the output voltage and delivered to the amplifier input as current (we have a current-input amplifier). Thus, we have a case of shunt-voltage feedback, which is shown in its general form in Fig.7.

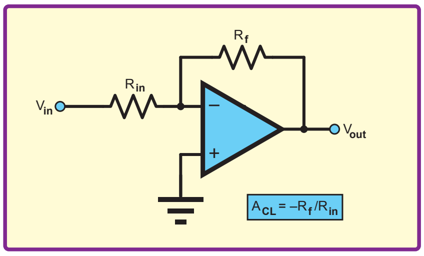


Fig.4. Op amp inverting amplifier

We have already argued that the voltage at the inverting input is close to zero, so the voltage across R_f is equal to V_{out}. Thus, $i_f = V_{out}/R_f$.

You may have spotted that the feedback currents are drawn in different directions in Fig.6 and Fig.7. This is because there is a minor discrepancy between the circuit in Fig.6 and the general feedback amplifier structure shown in Fig.2.

The gain of our amplifier is negative (increasing magnitude of positive input current gives increasing magnitude of negative output voltage), whereas the amplifiers in Fig.2 and Fig.7 have positive gain. We can redraw the feedback structure as shown in Fig.8 to account for this. The loop gain (βA) must still be negative for negative feedback to occur, so we have to add, rather than subtract, the signal from the feedback network to the input signal. This accounts for the feedback current direction in Fig.6.

We can analyse the structure in Fig.8 in exactly the same way as we did with Fig.2 last month. We get:

$$A_{CL} = -\frac{A}{(1+\beta A)}$$

The only difference being the minus sign. Similarly, for a very large A, we can make an approximation:

$$A_{CL} = -\frac{1}{\beta}$$

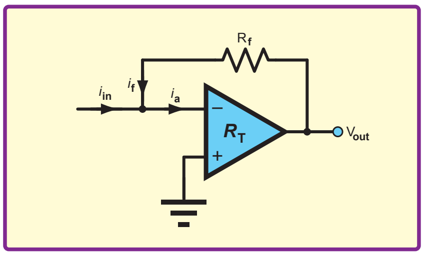


Fig.6. Transresistance amplifier with feedback

Looking at Fig.6 in feedback theory terms, we are multiplying the output signal by $1/R_f$ to get the feedback signal, so:

$$\beta = \frac{1}{R_f}$$

Furthermore, given that we have very high amplifier gain we can use the approximate form of the feedback equation:

$$A_{CL} = -\frac{1}{\beta} = -R_f$$

The closed loop gain of the circuit in Fig.6 is $-R_f\Omega$. That is:

$$\frac{V_{out}}{i_{in}} = -R_f$$

Referring back to Fig.4 we recall that we generated i_{in} from V_{in} using R_{in} such that $i_{in} = V_{in}/R_{in}$. Substituting this into the above equation we get:

$$\frac{V_{out}R_{in}}{V_{in}} = -R_f$$

So voltage gain of the circuit is:

$$A_{CL} = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

which is what we would expect for the gain of the inverting op amp amplifier. This formula is applicable to both the op amp and transistor circuits, but for the transistor circuit it is a relatively poor approximation due to the low open-loop gain of Q1/R_C.

To perform this analysis, we converted Fig.4 into Fig.6. This was a valid approach, but readers might be wondering if we can analyse the whole of the circuit in Fig.4 more directly in terms of a feedback structure. The answer is, we can, but such a feedback structure will not be exactly the same as Fig.2.

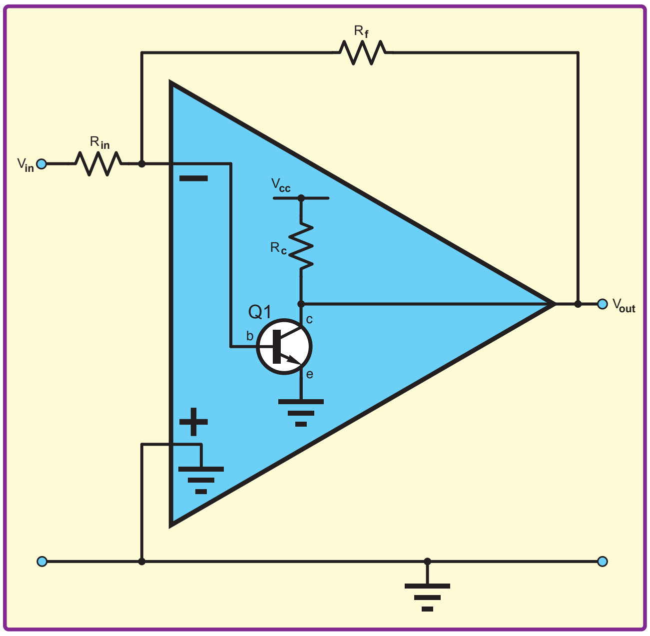


Fig.5. Schematic from Fig.1 redrawn to show correspondence with Fig.4

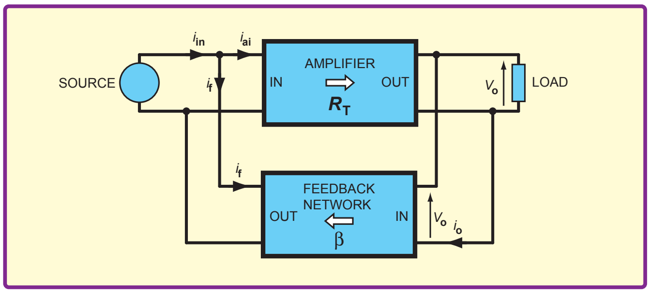


Fig.7. General form of a shunt-voltage feedback

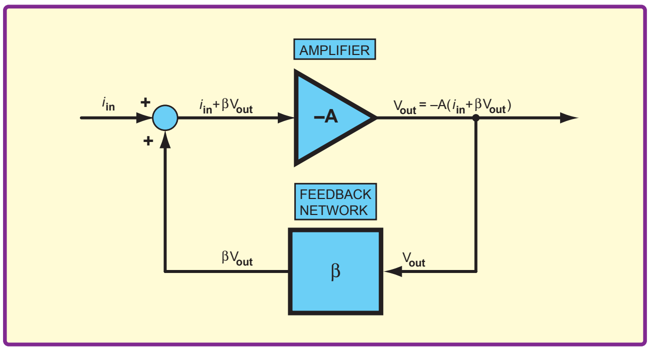


Fig.8. Amplifier feedback structure for Fig.6

We have already encountered one difference when analysing Fig.6, namely that our amplifier has negative rather than positive gain. When considering Fig.4 we have a further issue that the input signal is not fed directly to the amplifier (mixed with the feedback), but is applied via the resistor network.

With Fig.4 we are dealing with a voltage amplifier, so we need to find the feedback in terms of voltage, rather than current as we did previously. The resistors R_f and R_{in} are connected in series between V_{in} in and V_{out}. If we assume the op amp has very high input impedance then the voltage at the junction between the resistors (the op amp input) will depend only on V_{in} and V_{out} (the op amp will not load the resistor network).

To analyse a *linear* circuit with multiple sources (voltage or current) we can work out the contribution of each source individually and simply add up these contributions (by the definition of linear). All the sources are set to zero apart from the one we are working on at the time.

To find the voltage contribution of V_{out} at the amplifier input (that is the feedback) we simply set V_{in} to zero. This means that R_f and R_{in} can be regarded as a potential divider connected from V_{out} to ground. The feedback voltage is the potential divider voltage, that is:

$$V_f = \frac{R_{in}}{R_{in} + R_f} V_{out}$$

From which we get:

$$\beta = \frac{R_{in}}{R_{in} + R_f}$$

If we applied:

$$A_{CL} = -\frac{1}{\beta}$$

We would get:

$$A_{CL} = -\left(1 + \frac{R_f}{R_{in}}\right)$$

but this is not what we know the gain of the inverting op amp amplifier to be.

The problem is that we have not taken the effect of the resistors on V_{in} into account. Setting V_{out} to zero we see that the resistors act as a potential divider connected from V_{in} to ground. Writing this voltage as 'effective input voltage' $V_{in,eff}$ we get:

$$V_{in.eff} = \frac{R_f}{R_f + R_{in}} V_{in}$$

Comparing this with the expression for feedback voltage (which of course involves the same resistors the other way round) we can show:

$$V_{in.eff} = (1-\beta)V_{in}$$

Adding the contributions of the two sources to the voltage at the input of the op amp we get:

$$V_{ia} = V_f + V_{in.eff} = \beta V_{out} + (1-\beta)V_{in}$$

Thus, referring to Fig.2, we see that for this circuit we do not have S_{ai} = S_{in} + S_f as implied by Fig.2. We need to use a different feedback structure to represent this circuit. This is shown in Fig.9.

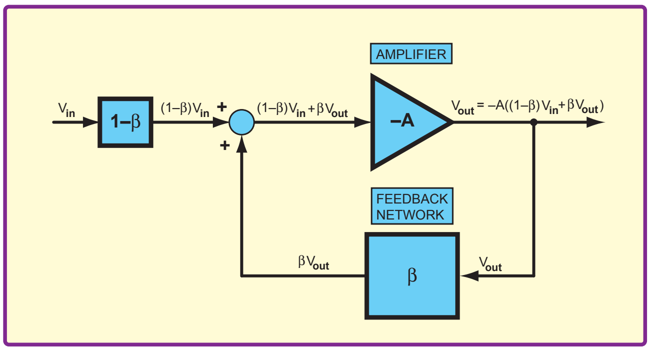


Fig.9. Amplifier feedback structure for Fig.4.

Referring to Fig.9, we see that the output of the circuit is given by:

$$V_{out} = -A((1-\beta)V_{in} + \beta V_{out})$$

From which, as we did last month with Fig.2, we can find the closed-loop gain:

$$A_{CL} = \frac{V_{out}}{V_{in}} = -\frac{(1-\beta)A}{(1+\beta A)}$$

So, Lost was correct when stating that the standard feedback equation did not apply to his circuit. For a very large A we can also make the approximation (1+βA)= βA and hence simplify the closed-loop gain to:

$$A_{CL} == \frac{(1-\beta)}{\beta} = -\left(\frac{1}{\beta} - 1\right)$$

Previously we found for this circuit:

$$\beta = \frac{R_{in}}{R_{in} + R_f} \quad \text{so} \quad \frac{1}{\beta} = 1 + \frac{R_f}{R_{in}}$$

From which, using the approximate formula for A_{CL} we have just obtained, we get:

$$A_{CL} = -\frac{R_f}{R_{in}}$$

as expected for an inverting amplifier. We are happy to see that this is the same result as we got using the transresistance amplifier based analysis of the circuit.

If we have Fig.4 with R_f = 400kΩ and R_{in} = 40kΩ we get a β of 0.09091 giving a gain of –(11–1) = –10 using –(1/β – 1). If the op amp gain is 100,000 the full feedback equation gives the gain as 9.9989. We see the approximate equation provides us with an accurate value.

Desensitisation

For Fig.1, the open-loop gain is considerably smaller; it could easily be around 100, depending on the transistor gain, power supply and R_C. Using R_f = 400kΩ and R_{in} = 40kΩ we get a closed-loop gain of 10 using the approximate feedback equation, and about 9 using the full equation. The error of 10% may lead us to doubt the justification of using the approximate equation in this case.

If we double the open-loop gain for Fig.1 to 200, we find the closed-loop gain shifts to about 9.5. The higher gain reduces the error in the approximate calculation, but more importantly this demonstrates that the negative feedback is indeed doing its job in desensitising the circuit gain to variations in transistor gain. A doubling of open-loop gain resulted in just a 5% shift in closed-loop gain. For an op amp based version of Fig.4, the open-loop gain desensitisation is much stronger.

In Fig.1, the desensitation provided by the negative feedback is not only important for fixing the circuit gain against the variation in transistor gain, but also in helping to provide a stable operating point (bias) for the transistor. In some applications of the circuit the signal feedback and its consequent gain reduction may not be desirable.

If R_f is split into two resistors in series and the midpoint is connected to ground via a suitable capacitor the circuit receives DC feedback to stabilise the bias, but signal feedback is removed by the capacitor coupling the signal to ground.

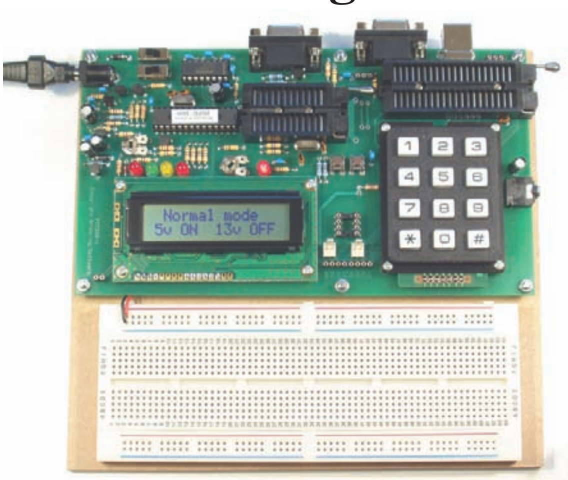
We have seen that the approximate feedback equation is inaccurate for the circuit in Fig.1. This is not the only problem with our use of approximations in the analysis of this circuit. In working out the feedback current and voltage we assumed that the amplifier did not have any input current. This is a good approximation for a modern op amp, but far less so for the transistor circuit in Fig.1.

Similarly, we assumed that the (signal) input voltage to the amplifier was almost zero, again this is a good approximation for an op amp circuit, but far less so for the transistor one due to its much smaller gain.

The feedback structures shown in Fig.2 and Fig.8 imply that both the amplifier and feedback network are unilateral (only pass the signal in one direction). This is a good approximation for the op amp, but less so for the transistor because of the reverse gain that transistors exhibit.

We have answered Lost's question by showing how abstract feedback structures and related equations can be applied to the circuit in Fig.1. We have seen that this allows us to appreciate the stabilising effect of feedback. In other circuits, attempting an analysis in terms of feedback theory may be even more difficult – there may be more than one type of feedback occurring simultaneously.

PIC Training Course



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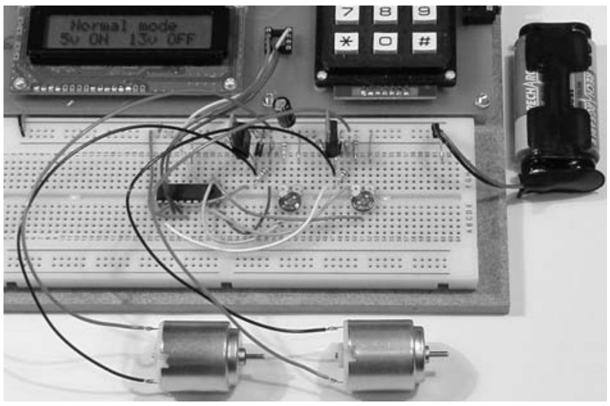
Telephone with Visa, MasterCard or Switch, or send cheque/PO. All prices include VAT if applicable.



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Max's Cool Beans

By Max The Magnificent

Beware the white screen of death

Do you remember the 'Blue Screen of Death' that used to be the hallmark of the earlier Windows operating systems as they crashed and burned? Well, Windows 7 seems to favour a misty white flavour, which is a little less harsh on the eyes, but which is no more welcome than its predecessor. I know, because this happened to me little more than a week ago as I pen these words.

I almost lost my working data – about 1.2GB of current projects and 'stuff' that I like to keep handy. This would have been a disaster, because I had a couple of projects that were due to be delivered the following day.

I know, I'm old enough to know better. The thing is that I have a 1TB external USB disk sitting on my desk at work. At the end of each day, just before I head for home, I take a copy of my working files. The problem was that I had been working from home for a couple of days, so I didn't have a recent backup. Fortunately, the local computer repair store pulled out my hard drive and managed to burn a copy of my data files onto a DVD.

Colour me stupid. My data is one of my most valuable assets; I really need to take much better care of it, so I decided to come up with a cunning plan…

Backup computer system

One thing I have to do is to protect myself against a catastrophic loss of my main notepad computer. For example, suppose I left it in my office overnight and there was a fire – which would also take out my backup drive. That would not be good news. The solution here is to keep my notepad for use at home and while I'm on the road, and to get a second system for use in the office.

Since I won't be carrying it around with me, the system in my office can be an affordable tower computer. You wouldn't believe the deals that are out there. For only about $350 (US Dollars) I ended up ordering something of a beast – a refurbished Xeon-based machine with 4GB RAM, a 500GB hard drive, all the usual 'stuff' like DVD, sound, ethernet, and a mega-powerful dual DVI video card.

Actually, this first part of my plan was a little self-serving, because I recently purchased an incredible 28-inch monitor (**www.amazon.com/I-Inc-iH-282HPB-Class-Widescreen-Monitor/dp/B002YECKCQ**). I love this display! In fact, on the basis that I spend a minimum of eight hours a day slaving away at the computer, I'd been thinking about purchasing two more to give myself a mega-amazing desktop. Of course, I couldn't drive more than one of these monitors with my existing notepad – what I needed was an excuse to purchase a new computer… (grin). Of course, the video card in my new tower can drive only two monitors, but I picked up an identical (refurbished) card on eBay for only $35.

My next problem is ensuring that my data is absolutely identical on both machines…

Backing-up and synchronising data

There are a number of utilities one can use to synchronise data between two or more computers and other things like an external hard drive (sometimes even your Smartphone). For example, Syncables 360 (**www.syncables.com**) or GoodSync (**www.goodsync.com**). My original idea was to get a ruggedized external USB 2.0/3.0 hard drive that I would carry around with me, and then to use one of these programs to synchronise the data between this external hard drive and my home and work computers.

Fortunately, I was introduced to something called Dropbox (**www.dropbox.com**). This is absolutely fantastic, and it's also FREE, so long as you have less than 2GB of data to worry about – there's a small monthly cost for up to 50GB and a larger cost for up to 100GB, but as I mentioned earlier, I'm primarily worried about maintaining the integrity of my working data, which is only around 1.2GB.

So how does this work? Well, first of all you click the Download button on the Dropbox website and download and install the small Dropbox application. This creates a special Dropbox folder on your system (I told it to put this folder under my existing My Documents folder)

The Dropbox folder icon looks like a regular folder icon except for a small green circle with a tick-mark in the bottom left-hand corner. Next, you drag-and-drop any of your existing files and folders that you wish to backup into your Dropbox folder. At this point, the green circle on the folder icon turns blue, which indicates that the Dropbox application is copying your files into 'The Cloud,' by which I mean extremely secure servers. As part of this, all of your data is encrypted using the AES-256 standard.

This is where things start to get really cool and exciting. Whenever you edit a file and save it, that file is immediately backed up into the cloud. But wait, there's more, because you can now go to another system and install the Dropbox application on that machine. This time, instead of saying you are a new user, you say that you are an existing user and give your username and password. What happens now is that Dropbox synchronises the Dropbox folder on this new machine with your Dropbox folder in the cloud, so all of the files you saved from your other machine are now replicated on this new machine. And, of course, if you create any files in the Dropbox folder on this new machine, a copy is automatically pushed up into the cloud to eventually be synchronised with your other machine(s). You can do this for as many machines as you wish.

For me, Dropbox is a perfect solution. As soon as I create a new file or modify an existing file, that file is immediately backed up into the cloud. And the fact that my data files are automatically synchronised across all of my machines is worth its weight in gold!

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

IT depends on the particular project in question, but once the circuit board and the cutting and drilling of the case have been completed, an electronic project is usually getting very close to completion. On the other hand, with a significant proportion of projects there is still some way to go.

The circuit board has to be mounted in the case, and it will usually be necessary to add a certain amount of hard wiring to connect the circuit board to any controls, sockets, or other components that are not fitted on the board. The modern trend is to have as much as possible fitted on the circuit board, but with some projects there is a substantial amount of hard wiring to add.

It is only natural to be in a hurry to finish the project at this stage, but it is important to thoroughly check the circuit board for errors. Also, check the underside of the board for any bad or omitted joints, and for short circuits caused by excess solder. Bear in mind that once the project is completed it is very unlikely that it will be possible to fix a problem with the board, unless it is disconnected from any off-board components and removed from the case.

You can save a great deal of time and effort by getting the circuit board just right before it is installed in the case. This also avoids the slight risk of damaging something when dismantling and rebuilding the project.

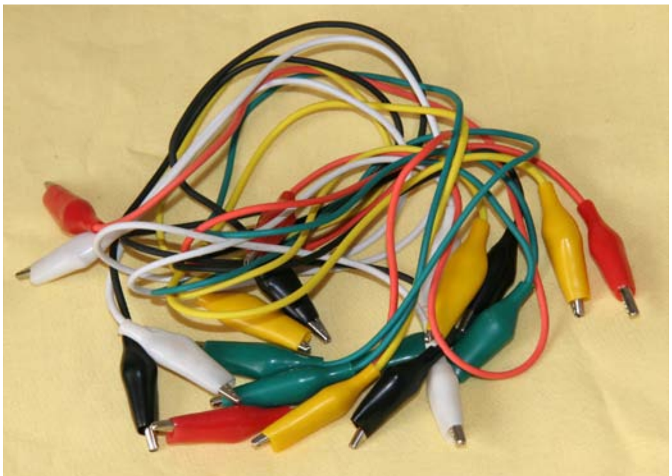

Fig.1. Short leads with a plastic-covered crocodile clip at each end are useful for making temporary connections. A set of ten is a very useful addition to the workshop

Pretesting

I am always much happier if the circuit board is tested and perfected prior to it being fitted into the case. Should a finished project fail to work, having pretested the circuit board you will know that the problem almost certainly lies in some other part of the unit.

Assuming the board was not damaged during the installation process, the problem has to be in the hard-wiring. The other possibility is that something on the board is coming into electrical contact with the metal case or chassis, or with an off-board component.

Modern projects tend to cram quite a lot into a small amount of space. This can lead to a problem with the project working when the lid of the case is removed or the project is partially dismantled, but failing to work when everything is put back into place. A quick investigation of the problem will usually reveal the cause. The cure is usually something very simple, such as bending the tag of a component into a slightly different position, or adding a piece of insulation tape at the appropriate position on the underside of the lid.

With some projects there is no difficulty in pretesting the board, because practically all the components are installed on the board. It just has to be connected to the battery and then testing can commence. At the other extreme, there could be numerous wires needed to carry connections from the board to various controls, sockets, or whatever.

Being realistic about things, it will sometimes be difficult to justify the time and effort involved in pretesting the circuit board. However, where the pretesting would be very time consuming, it would still not be nearly as time consuming as removing a faulty circuit board and installing it again.

The long and short of it!

A ploy I have used successfully is to complete the hard-wiring before fitting the circuit board and off-board components into the case. The length of the wiring has to be carefully gauged so that it is not too short or excessively long, and it is a technique that might not be applicable to all projects, but it works well in many instances. If there should be a problem, it is very easy to check any aspect of the unit since there is no case to hinder access to any part of circuit board or wiring.

It is advisable not to use the normal technique for hard-wiring if you add some temporary wiring for testing purposes. The usual method is to hook the end of the wire through and around a tag that has a hole, or to bind it around a pin or tag that does not. Then the wire is soldered in place. This gives a joint that is mechanically and electrically excellent, but it can be difficult to undo the connection.

For temporary connections, it is better to tin the end of the wire and the pin or tag with a generous amount of solder so that they can then be easily joined without the need for hooking or binding the wire first. The resultant joint with be electrically good, but mechanically weak. However, it will be good enough for temporary purposes, and it can be undone by simply applying the bit of the iron to the joint. The wire will then free itself. It might be possible to use crocodile clip leads if only a few connections are required (see Fig.1).

Connections to the circuit board, whether temporary or otherwise, must always be made via a solder-pin of the correct diameter and never directly to the copper pad. A solder-pin should be a tight fit into the hole in the circuit board so that any pulling, pushing, or twisting of the wire will be resisted by the pin. Unless grossly excessive force is used, no strain will be placed on the copper pad. All the strain will be placed on the pad if no pin is used, and due to the small size of a typical

copper pad it will be easily ripped away from the board and the copper tracks. A solder-pin is the wrong size if it is a loose fit in the board. Connections made via a loose-fitting pin will be as unreliable as those made directly to the board.

A final, but important, point about pretesting is that it is only applicable to projects that are battery powered, or are powered by a separate mains adapter unit. Any testing of a mains powered project can be tricky and *potentially lethal*. It is definitely **NOT** something that a beginner should attempt.

Mounting tension

It is important that the circuit board is fitted into the case in such a way that there is no significant risk of it coming free and causing short-circuits. The obvious method is to simply bolt it in place, but this method is slightly less straightforward than you might think.

When the board is mounted on a metal case or chassis it is clearly essential to have the underside of the board held clear of the case or chassis. Some of the connections on the underside of the board will otherwise be short-circuited through the case or chassis.

Using some spacers between the board and the case, as in Fig.2, is all that is needed to solve this problem. The spacers are just tubes of a suitable diameter for the mounting bolts, and they are usually made from steel. The spacers are normally between about 6mm and 25mm in length, and it is advisable not to use anything much less than about 6mm.

One could be forgiven for thinking that spacers are unnecessary when using a case or chassis made from a non-metallic material. However, the spacers are still required even if the case or chassis are made from plastic, wood, or any other material that does not readily conduct electricity.

They would not be necessary if the underside of a circuit board was completely flat, but it is not. The problem is the soldered connections that protrude a few millimetres on the underside of the board, making it impossible for the board to fit flat neatly against the case.

Unless spacers are included, the board becomes distorted as the mounting nuts are tightened, with the areas of the board around the mounting bolts being forced right down onto the case. This places stresses on both the board and the case, and could result in one or both of them being damaged.

Spacers are available in plain and threaded versions, with the latter having a screw-thread running the full length of the tube's interior. It is probably easier to use the threaded type when mounting large boards that require several mounting bolts. With threaded spacers you can fix them all onto the mounting bolts, place the board in position, and then add the fixing nuts. Alternatively, the spacers can be fitted to the case using short mounting bolts, and then a separate set of short bolts can be used to fix the circuit board on the spacers.

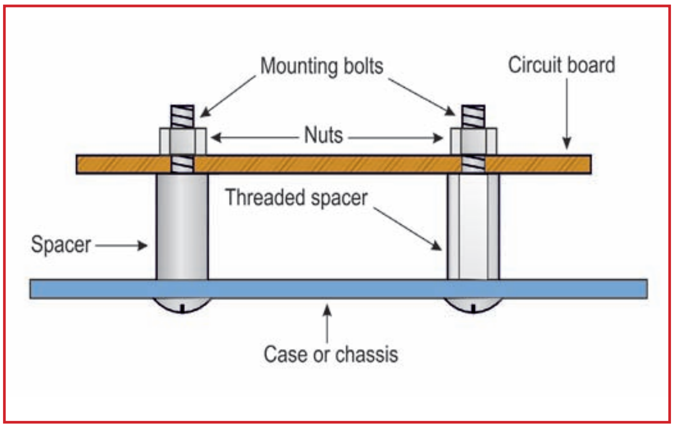

Fig.2. Using plain (left) or threaded (right) spacers over the mounting bolts keeps the underside of the board clear of the case. Spacers about 6mm long are normally sufficient

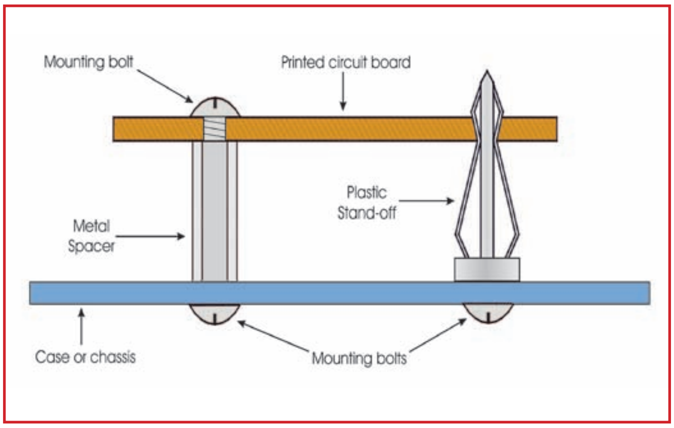

Fig.3. Some stand-offs use mounting bolts at both ends (left), and are much the same as threaded spacers. A common variation on this (right) is to have the stand-off bolted to the case, with the circuit board just clipped into place

Using plain spacers tends to be fiddlier because the bolts and spacers have to be held in place while the board and fixing nuts are added. If you run out of fingers, using Blu-Tack or Plasticine to temporarily hold things in place can make the job much easier.

Any error in the positioning of the mounting holes in the case tends to place both the case and circuit board under stress. This might not happen when using threaded spacers, since significant positioning errors will make it impossible to fit the circuit board onto the mounting bolts!

Assuming that the error is only a millimetre or two, using a needle file to slightly elongate the mounting holes in the case and (or) circuit board will usually be sufficient to get the board in place. Very slight adjustments of this type are often required, but greater care needs to be taken if anything more than minor adjustments are needed on a regular basis. The circuit board itself can often be used as a template when marking the positions of the mounting holes on the case or chassis, and this should aid good accuracy.

Stand-offs

Various types of plastic or metal stand-offs provide the main alternative to using mounting bolts and spacers. Some of these are essentially the same as threaded spacers, or are slight variations on this basic way of doing things. For example, one type has the usual threaded hole at one end, and a short threaded rod section at the other. One end is mounted on the case or chassis using a fixing nut, and the board is mounted on the other end using a short bolt. It could just as easily be used the other way around.

Some stand-offs are much like a threaded spacer, but have plastic bodies with metal inserts. They are used in the way shown in Fig.3 (left), which works just as well with threaded spacers.

Most of the plastic stand-offs are designed to clip into place at both ends, or to be bolted to a case at one end and clip into the circuit board at the other (Fig.3 – right). Again, there are variations, such as a type that has a self-adhesive pad at the case end and which clips into the circuit board at the other end.

Although in some ways a neater solution than using spacers and mounting bolts, plastic stand-offs do not usually fix the board in place quite as securely. In fact, it is usually necessary to get things just right for them to work at all. Unless the mounting holes are drilled cleanly and very accurately, it will probably be impossible to clip the stand-offs into the holes or they will clip into the holes but will unclip just as easily.

Stand-offs that clip into the case or chassis work best where the circuit board will be mounted on a chassis within the case. Fitting them directly onto the outer casing does not work too well because the clips protrude a few millimetres from the surface of the case. This would probably look a

bit unsightly, and it is likely that the clips would get knocked out of place, leaving the circuit board rattling around loose inside the case.

I have never found any type of stand-off that clips to the board to be of much use with stripboard. The problem seems to be that the matrix of pre-drilled holes in the board prevents really neat mounting holes from being produced. Enlarging one of the existing holes to a suitable size tends to result in it merging with the four nearest pre-drilled holes.

The resultant mounting hole is far from being perfectly circular, which seems to be sufficient to prevent most stand-offs from clipping into place reliably. Mounting bolts and spacers or stand-offs that have the board bolted in place are a much better choice with stripboard.

In the groove

The simplest method of mounting circuit boards is to use guide rails that are moulded into the interior of the case. Obviously, this method does not apply to the vast majority of cases because they simply do not have the guide rails. However, they are to be found in many plastic cases and boxes, and in some metal or metal and plastic types.

Although an excellent idea, built-in guide rails do have a few limitations in practice. The most obvious one is that the board has to be just the right size in order to fit into the rails. This will not be the case with a ready-made board, unless it has been designed specifically to fit the case you are using. With a home produced board it might be possible to make it deliberately oversize so that it fits the rails.

The rails in most cases are rather minimalistic, making it necessary to have the board exactly the right size in order to obtain a good fit. Make it fractionally too large and it will not fit into the case, or slightly too small and it will drop straight out of the rails. The cases that have guide-rails often have a slightly tapered shape, and it is sometimes necessary to file the board to get a really good fit.

Some plastic cases have built-in stand-offs that are either designed for use with self-tapping screws (Fig.4), or have metal inserts that take ordinary mounting bolts. Like built-in guide-rails, these stand-offs are often of little practical value, because the board has to be designed specifically to fit them. In most cases they are an encumbrance rather than an asset, and they can get in the way when trying to install the circuit board.

The type that does not have the metal inserts are easily drilled away using a drill bit slightly larger than the diameter of the built-in stand-offs. The kind that have metal inserts are more difficult to deal with, and it is probably better to work around them rather than trying to remove them.

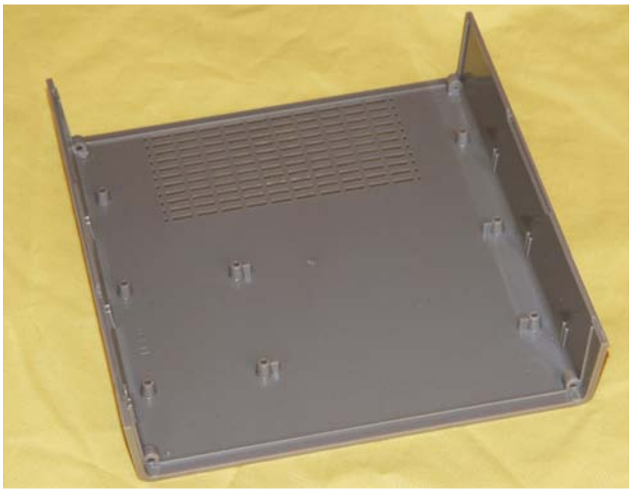

Fig.4. Plastic cases often have built-in stand-offs. These are potentially useful, but in practice they are often just unwanted obstructions

READOUT

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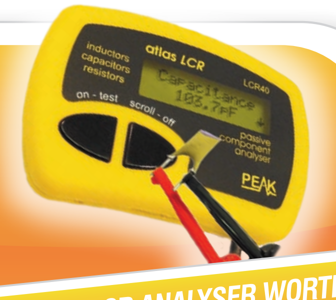
Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly



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☆ LETTER OF THE MONTH ☆

R-S flip-flops

Dear Editor
First, please convey my congratulations to Mike and Richard Tooley for their excellent *Teach-In 2011* series.

I would like to extend their discussion of R-S bistables, covered in *Teach-In 2011*, Part 6. I fully agree with their description of bistable operation, as presented on page 48 when it is applied to the NOR gate configuration (Fig.6.14b), whereby both inputs are held low and the relevant input is taken high momentarily to set or reset the Q output.

However, what is not mentioned in the feature is that the NAND-gate configuration bistable functions differently to the NOR-gate configuration in that both its inputs are normally held high, and each one is taken low momentarily to control the Q output. This issue would be partially clarified if, in Fig.6.14a, the input labels of the NAND-gate bistable were swapped over with each other in relation to the output labels, and bars inserted over the words SET and RESET to indicate that they are in fact active low signals.

Mike and Richard reason that these configurations of bistables have 'serious shortcomings', and they go on to say, 'Consider what would happen if a logic 1 was simultaneously present on both the SET and RESET inputs!' Well, in response, I would reason that these forms of bistable are eminently practical, assuming that all the combinations of input values that could possibly occur in the circuit are catered for in each design.

For example, in Jim Rowe's *PIR-Triggered Mains Switch* constructional project (*EPE* April 2011), if human movement is still occurring when the selected timer output times out, then both the bistable inputs will be in the active state (both low) and the Q-bar output (Pin 4) of the flip-flop momentarily joins the Q output in the same high state, thus resetting the 4060B timer and initiating another time interval without the Q output (Pin 11) being affected. If, instead of momentary action, the reset input (Pin 6) were held low, then the Q output (Pin 11) would only reset low when the SET input (Pin 13) next returned high, thus latching the new condition.

Another concrete example of the situation where both the SET and RESET inputs of a bistable are held in the active state (both high in this instance) is when a 555 timer, configured in monostable mode, has its trigger input held low beyond the required output pulse width. In this situation, the Timer output will only reset low when the Trigger input is next returned high.

Jim Rowe has used this form of bistable to very good practical effect over the years; consider just two more examples: the *Phone/Fax Missed Call Alert* (*EPE* Jan 2008) and the *Time Delay Photoflash Trigger* (*EPE* Feb 2011).

I do appreciate that Mike and Richard are aiming their series at the Level 2 syllabus for the new Diploma and BTEC units for the First Award Programme. The above discussion is for those who wish to know a bit more by looking a little deeper, and I hope that Mike and Richard will also appreciate some positive feedback and that they won't mind too much me attempting to be a champion of the humble, much maligned, yet very useful R-S bistable!

Chris Hinchcliffe, Dorset

Thank you Chris, extra insight is always welcomed, and I am sure Mike and Richard do not mind your observations. As you rightly point out, Teach-In *cannot, and indeed should not hope to cover all aspects of a topic. It would become far too complex and thereby defeat its whole purpose, which is to be a clear and concise introduction that inspires readers to further exploration.*

The future of amplification

Dear Editor
I have often pondered on what the final, ultimate, affordable format of hifi amplifiers will be. For now, forget multi-kilowatt, ultra expensive extravaganzas and complicated surround-sound, seven-channel audio/video units, with built in microprocessors permitting wonderful digital manipulation of the input signal – I'm just talking about 'amps'.

If you look at amplifiers in the 20W to 150W range, you will notice a striking similarity between circuits. This is even more noticeable in the case of valve amps. My Williamson of 1957 bears a good resemblance to modern amps, even to the valves used. In the case of high-end pre-amps, we seem to have settled on ICs requiring a handful of components. The power supply on my Naim 115W amp, dating from 1980 or thereabouts, is a massive affair; whereas some high-end amps today use switch-mode power supplies.

It seems the Holy Grail of amplification, a Class-A amp requiring massive heatsinks and sizeable PCBs is being challenged by class-D at 20% the size and cost.

Some enlightened comment from knowledgeable readers and contributors should make for interesting reading!

Leon van der Merwe, by email
Pretoria, South Africa

A good question Leon, and I'm sure there will be many good, but contradictory answers. Amplifier and power supply design decisions can be as much about personal taste as equations and data sheets. I remember being surprised when Linn launched their 'switcher' supply for some very expensive amps. It went quite against all the received wisdom I had absorbed, but the result was some extremely good products. So, what do our readers think is the best route to amplifier heaven?

Flashes of inspiration

Dear Editor
Following on from the email from L van der Merwe in the February issue, how nice it was to see a project in the same issue designed with real components – the *Time Delay Flash Trigger*. This is something that could have been designed using a PIC with an LCD and a few buttons to set the time delay, and made to fit into a much smaller case. Jim Rowe is to be congratulated for producing an excellent design which is much more instructive and easier to modify if required.

The article prompted me to dig out a flash trigger that I made 30 odd years ago from a design that I think was in *Electronics Today International* (*ETI*) – see photo. It is basically the same as Jim Rowe's design, but with the timing done using an analogue timer controlled with a variable resistor. A phototransistor was built into the front, which would allow it to

operate as a slave flash trigger, with or without delay, while a socket on the top allowed an external microphone or 'break beam' sensor to be used as a trigger. The whole thing was build into a small box with hot shoe fittings top and bottom to allow it to clip on to the camera and have the flash attached.

PICs are very useful at more complex tasks, but looking at circuit diagrams that consist of a processor with a power supply and a few external components will not teach very much about electronics design, while changing PIC code might not be possible for some people who may wish to modify the design. I know you can only publish what is submitted, but can we have more 'real' projects please.

Stephen Varley, Cheltenham

Many thanks for your letter, and I'm pleased you enjoyed the recent flash article.

I like the look of your hot shoe-mounted flash controller – very neat and tidy.

You raise a serious point with regard to PIC-based projects. We do try to avoid making every project a software-oriented one, but have to face the fact that many projects are greatly improved with the flexibility and reduced component count that PICs can provide. That said, circuits should always stay focused on the primary objective of the project and not become vehicles for superfluous software add-ons. The Hardware dog should wag the software tail – and not the other way around.

IF YOU HAVE A SUBJECT YOU WISH TO DISCUSS IN READOUT PLEASE EMAIL US AT:

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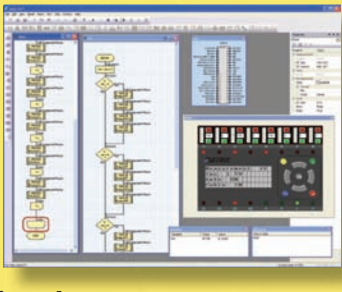
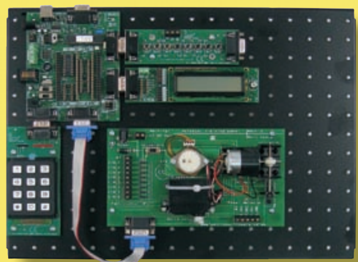


Simulate
Once your system is designed you can use Flowcode to simulate it in action. Design your system on screen, test the system's functionality by clicking on switches or altering sensor or input values, and see how your program reacts to the changes in the electronic system.



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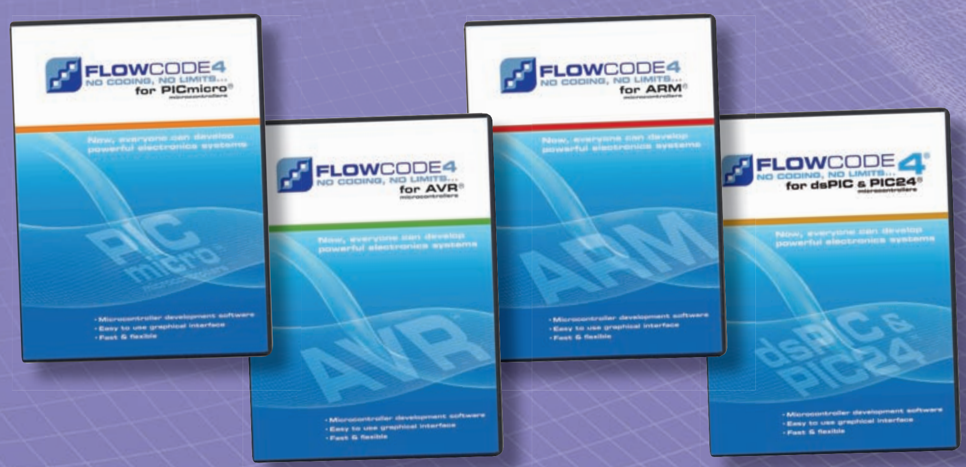
When you are happy with your design click one button to send the program directly to your microcontroller based target. Targets include a wide range of microcontroller programmers, upstream E-blocks boards, the Formula Flowcode robot, the MIAC industrial controller, or your own system based on ECIO technology.



FlowKit
The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your finished designs.

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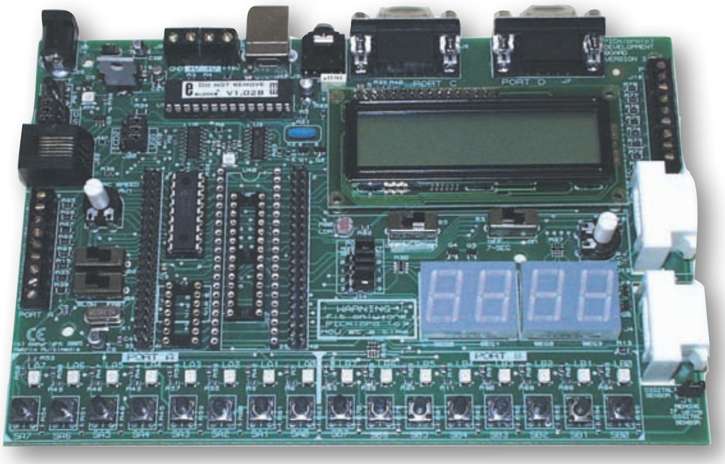

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SOFTWARE

ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

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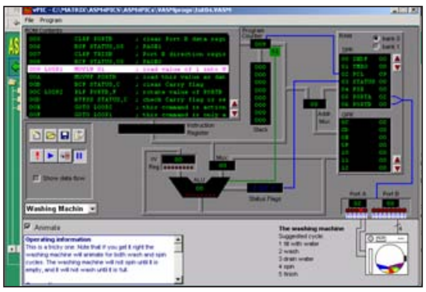

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The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

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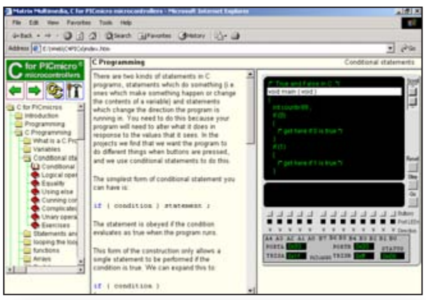

Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

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- Produces ASM code for a range of 18, 28 and 40-pin devices
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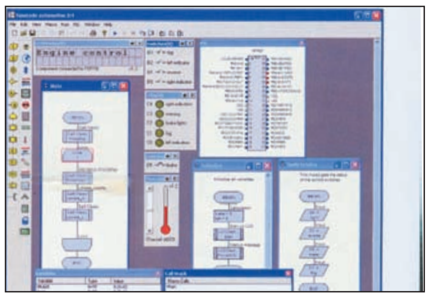
- I2C.

New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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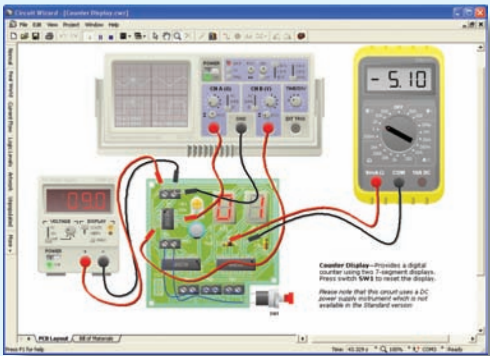

This is the software used in our *Teach-In 2011* series.
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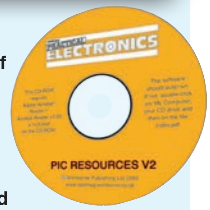
EPE PIC RESOURCES V2



Version 2 includes the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

The CD-ROM contains the following Tutorial-related software and texts:

- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
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Net Work

Alan Winstanley

LAST month, I suggested the Billion BiPAC 7800N router, a product that is targeted at the Small Office/Home Office (SoHo) user, as a replacement for my smaller consumer-type router that had become a little troublesome. The Billion brand is less well known than some popular names, and the 7800N is two or three-times more expensive than typical consumer devices, but it has many features to please the enthusiast, starting with far better ventilation for always-on use. It's reasonably futureproof too, as it accepts both ADSL and Ethernet WAN (cable) services and, in practice, it does seem to offer more robust and reliable WiFi.

Importantly for the writer, the 7800N incorporates a gigabit (1,000Mbps) 4-port switch to provide faster transfer rates on a gigabit-enabled local area network. Making multi-gigabyte backups, using the excellent Macrium Reflect backup software (**www.macrium.com**), has become less onerous and individual files can be restored within 30 seconds or so.

Wireless security

Wireless security can be frustrating to sort out, especially if there's a motley collection of devices to configure. Some hardware isn't compatible with new levels of security, but many routers, including the Billion offer mixed modes (ie,WPA/ WPA2-PSK), so an older device that uses WPA-PSK may still function. Very old WiFi hardware may only use WEP encryption, which is not compatible with my router settings: a card in a legacy Windows 98 machine had this problem. It's worth checking your network software for security compatibility before investing in major hardware upgrades.

After quickly configuring the new router, I fired up my various wireless devices and ensured they were configured to match the new network, and I was pleasantly surprised to find a strong WiFi signal, with laptops, phone and radio logging on virtually straight away. The Billion router is undoubtedly proving more powerful than its predecessors, and after several months of continuous use my wireless networking problems have all but disappeared.

Minor bugs and irritations have been noted, including the fact that the configuration web pages lock up if I forget to log out properly; the only way to log in again is to reboot the router. Trying to read the router's DHCP table causes a similar lock-up. Billion suggests that the anti-virus package or firewall may be the culprit, and perhaps a future firmware upgrade will cure these problems.

Annoyingly, I wiped all my router settings after flashing the firmware and restarting in factory default mode, as advised by Billion, which was not ideal, but the router's quick-start pages had me running again in no time. Other than that, the Billion 7800N has been rock solid, but a small number of online reviewers have described having mixed experiences using this router with their own ISP.

More options

The Billion SoHo router has many more features to appeal to experts, some of which are summarised briefly. The relatively new WiFi Protected Setup (WPS) is a more elegant way of setting up a wireless network, such as plug and play at the press of a button. Like the previous Tenda W300D, the Billion has a WPS pushbutton to initiate the setup process if WPS is used (and it's explained step-by-step in the user manual).

All wireless devices on the network must be WPS compatible though, so most of us will still hook up to the wireless network the hard way! An IT colleague had serious issues using WPS with another brand, and having deployed the same brand throughout the network it was scrapped because WPS just did not work at all.

The router firewall's packet filter can be set to allow or disable users from accessing certain IP addresses. Some bosses might want to block staff from spending hours on Facebook this way. A MAC address (Media Access Control) found on a WiFi device is its unique 'serial number'. For example, my Pure Evoke radio displays a MAC address of 00-13-E0-CC-57-10 and my phone, laptops and various wireless NICs each have their own MAC addresses. By using the Billion router's MAC filter, I could configure rules to only allow 'approved' devices to hook to my wireless network, blocking any other device by default.

Port mapping (found under the Virtual Server configuration) is an essential feature for some, as it allows external services to be routed to a defined port on your network. This might be needed, for example, if you are operating an IP webcam (a server in its own right) from behind the router.

I could optimise the network performance further via the quality of service (QoS) parameters in the router setup. Using QoS, I could prioritise different network services (web, email, etc) to help shape the traffic being uploaded, which might be worthwhile for some applications. As befits the Billion's higher cost, more options, too numerous, to list are available to appeal to power users.

Devolo dLAN 500 is part of a new breed of Homeplug mains networking devices for today's HDMI and AV application users

Through the mains

If WiFi or Ethernet cabling don't work for you, or a legacy device cannot offer the wireless security needed (eg, an old Windows 98 machine), then one alternative to consider is Homeplug networking, a system of streaming Ethernet through the electrical mains supply around your home. The latest Homeplug devices are faster, more compact and more energy-efficient than ever. You can connect computer peripherals, video or games consoles this way, typical operating 8 to 10 devices per network.

The new Devolo dLAN 500 AV Mini streams [up to] 500Mbps for HDMI, 3D video and multimedia networking over existing mains cable up to 300 metres long. Netgear's forthcoming Powerline AV500 does the same job. It is simplicity itself to set up, and if data security is an issue then software may be supplied that encrypts data from end-to-end.

Billion also manufactures a number of appealing Homeplug devices: the BiPAC 2074 has an AC Pass-Through mains socket with additional mains filtering that hopefully combats noise, and all Billion Homeplug adaptors can be rotated using a clip to offer the desired orientation. At a time when the broadband industry is being heavily criticised for misrepresenting ADSL data rates ('up to 20Mbps' often means 2 to 3Mbps in practice), I appreciated the realistic summary of Homeplug capability published by Billion at: **www.billion.uk.com/product/powerline.htm**.

As Billion explains, Homeplug can be prone to interference from mains-borne noise; my own Homeplug 85Mbps network gradually started to degrade and the cause was pinpointed to an older PC power supply. Like ADSL, the further away the Homeplug device, the slower the data transmission rate will be. If possible, try to borrow a Homeplug system first, or buy on a money-back guarantee.

That's all for this month – remember you can discuss with fellow readers in our forum at **www.chatzones.co.uk** or write to us at **editorial@epemag.co.uk**

The Billion BiPac 2074 is a unique Homeplug adaptor with a filtered AC pass-through feature

Ingenuity Unlimited

Readers' Circuits

We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas must be the reader's own work and **must not have been published or submitted for publication elsewhere.** The circuits shown have NOT been proven by us. **Ingenuity Unlimited** is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: Ingenuity Unlimited, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU.

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Our regular round-up of readers' own circuits

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If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC-based oscilloscope could be yours. After every 20 published IU circuits, Pico Technology will be awarding a PicoScope 3206 digital storage oscilloscope for the best IU submission. In addition a PicoScope 2105 Handheld 'Scope worth £199 will be presented to the runner up.

Simple Door/Window Alarm – *On guard*

IN THESE hard times, when few persons can afford an outside alarm, I offer this simple door/window alarm.

If you are watching TV in the front room, a burglar may break into the back room, steal your car keys and ransack the house without you being aware until the programme has finished. However, if you fit a sensor to the window and another to the door of the back room you will know immediately if either is opened because the buzzers emit a high screeching sound.

Before watching the TV, close the window and door, then switch the alarm on.

Even though the burglar may re-close the window/door, the alarm is latched and will sound continually until you turn it off.

The alarm is quite simple, there are no timer circuits. The response is almost immediate, continuous and latched.

Circuit details

The full circuit diagram for the Simple Door/Window Alarm is shown in Fig.1. It comprises two normally-closed (NC), magnet-actuated, reed switches feeding into IC1a, a 4093B quad two-input NAND Schmitt gate. IC1b switches transistor TR1, which drives the warning buzzers WD1 and WD2.

A pulsing buzzer and steady buzzer are connected in parallel. The buzzers must be fixed to a rigid base for maximum resonance. A red flashing LED (10mm 9V to 12V) can also be fitted in parallel with the buzzers.

All unused inputs of IC1 should be taken 'high' or 'low (0V)'. Alternative PNP transistors to the AC128 are BC307C or BC640.

The reed switches are mounted in/on the door or window frame and the magnets on the window or door, adjacent to the switches. Additional, normally-closed, reed switch sensors can be connected in series with the existing circuit switches to protect other vunerable entry points.

Although the circuit is fairly straightforward, I have not seen it used before in any publication as an alarm. It is cheap and effective and has been working efficiently for the last six months.

I hope you will publish this much-needed circuit.

Ken Barry,
Thornton-Cleveleys

INGENUITY UNLIMITED

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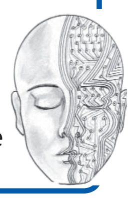

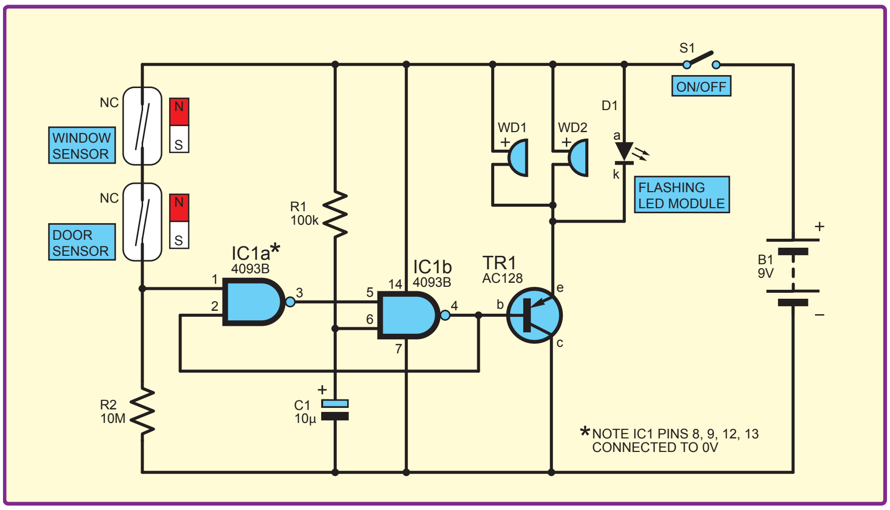

Fig.1. Complete circuit diagram for the Simple Door/Window Alarm

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NEW

Electronics Teach-In 3

FREE CD-ROM

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered.

Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 different circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series.

The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

CD-ROM — **Order code ETI3** — **£8.50**

CIRCUITS AND DESIGN

A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold

This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages — **Order code BP332** — **£5.45**

PRACTICAL ELECTRONICS CALCULATIONS AND FORMULAE
F. A. Wilson, C.G.I.A., C.Eng., F.I.E.E., F.I.E.R.E., F.B.I.M.

Bridges the gap between complicated technical theory, and "cut-and-tried" methods which may bring success in design but leave the experimenter unfulfilled. A strong practical bias – tedious and higher mathematics have been avoided where possible and many tables have been included.

The book is divided into six basic sections: Units and Constants, Direct-Current Circuits, Passive Components, Alternating-Current Circuits, Networks and Theorems, Measurements.

256 pages — **Order code BP53** — **£5.49**

MICROCONTROLLER COOKBOOK
Mike James

The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages — **Order code NE26** — **£36.99**

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS AND CDROMS SEE THE UK SHOP ON OUR WEBSITE
www.epemag.com

All prices include UK postage

2

COMPUTING AND ROBOTICS

WINDOWS XP EXPLAINED
N. Kantaris and P. R. M. Oliver

If you want to know what to do next when confronted with Microsoft's Windows XP screen, then this book is for you. It applies to both the Professional and home editions.
The book was written with the non-expert, busy person in mind. it explains what hardware requirements you need in order to run Windows XP successfully, and gives an overview of the Windows XP environment.

The book explains: How to manipulate Windows, and how to use the Control Panel to add or change your printer, and control your display; How to control information using WordPad, notepad and paint, and how to use the Clipboard facility to transfer information between Windows applications; How to be in control of your filing system using Windows Explorer and My Computer; How to control printers, fonts, characters, multimedia and images, and how to add hardware and software to your system; How to configure your system to communicate with the outside world, and use Outlook Express for all your email requirements; how to use the Windows Media Player 8 to play your CDs, burn CDs with your favourite tracks, use the Radio Tuner, transfer your videos to your PC, and how to use the Sound Recorder and Movie Maker; How to use the System Tools to restore your system to a previously working state, using Microsoft's Website to update your Windows set-up, how to clean up, defragment and scan your hard disk, and how to backup and restore your data; How to successfully transfer text from those old but cherished MS-DOS programs.

264 pages — **Order code BP514** — **£7.99**

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages + Large Format — **Order code BP901** — **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Covers the Vision command system

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

298 pages — **Order code BP902** — **£14.99**

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised third edition covers the popular reprogrammable Flash PICs: 16F54/16F84 as well as the 12F508 and 12F675.

270 pages — **Order code NE36** — **£25.00**

INTRODUCTION TO MICROPROCESSORS AND MICROCONTROLLERS – SECOND EDITION
John Crisp

If you are, or soon will be, involved in the use of microprocessors and microcontrollers, this practical introduction is essential reading. This book provides a thoroughly readable introduction to microprocessors and micrcontrollers. Assuming no previous knowledge of the subject, nor a technical or mathematical background. It is suitable for students, technicians, engineers and hobbyists, and covers the full range of modern micros.

After a thorough introduction to the subject, ideas are developed progressively in a well-structured format. All technical terms are carefully introduced and subjects which have proved difficult, for example 2's complement, are clearly explained. John Crisp covers the complete range of microprocessors from the popular 4-bit and 8-bit designs to today's super-fast 32-bit and 64-bit versions that power PCs and engine management systems etc.

222 pages — **Order code NE31** — **£29.99**

EASY PC CASE MODDING
R.A Penfold

Why not turn that anonymous grey tower, that is the heart of your computer system, into a source of visual wonderment and fascination. To start, you need to change the case or some case panels for ones that are transparent. This will then allow the inside of your computer and it's working parts to be clearly visible.

There are now numerous accessories that are relatively inexpensive and freely available, for those wishing to customise their PC with added colour and light. Cables and fans can be made to glow, interior lights can be added, and it can all be seen to good effect through the transparent case. Exterior lighting and many other attractive accessories may also be fitted.

This, in essence, is case modding or PC Customising as it is sometimes called and this book provides all the practical details you need for using the main types of case modding components including:- Electro luminescent (EL) 'go-faster' stripes: Internal lighting units: Fancy EL panels: Data cables with built-in lighting: Data cables that glow with the aid of 'black' light from an ultraviolet (UV) tube: Digital display panels: LED case and heatsink fans: Coloured power supply covers.

192 pages + CD-ROM — **Order code BP542** — **£8.99**

ROBOT BUILDERS COOKBOOK
Owen Bishop

This is a project book and guide for anyone who wants to build and design robots that work first time.

With this book you can get up and running quickly, building fun and intriguing robots from step-by-step instructions. Through hands-on project work, Owen introduces the programming, electronics and mechanics involved in practical robot design-and-build. The use of the PIC microcontroller throughout provides a painless introduction to programming – harnessing the power of a highly popular microcontroller used by students, hobbyists and design engineers worldwide.

Ideal for first-time robot builders, advanced builders wanting to know more about programming robots, and students tackling microcontroller-based practical work and labs.

The book's companion website at http://books.elsevier.com/companions/9780750665568 contains: downloadable files of all the programs and subroutines; program listings for the Quester and the Gantry robots that are too long to be included in the book.

366 pages — **Order code NE46** — **£26.00**

NEWNES INTERFACING COMPANION
Tony Fischer-Cripps

A uniquely concise and practical guide to the hardware, applications and design issues involved in computer interfacing and the use of transducers and instrumentation.

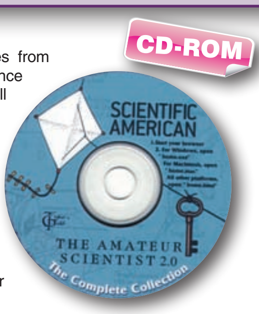
Newnes Interfacing Companion presents the essential information needed to design a PC-based interfacing system from the selection of suitable transducers, to collection of data, and the appropriate signal processing and conditioning.

Contents: Part 1 – Transducers; Measurement systems; Temperature; Light; Position and motion; Force, pressure and flow. Part 2 – Interfacing; Number systems; Computer architecture; Assembly language; Interfacing; A to D and D to A conversions; Data communications; Programmable logic controllers; Data acquisition project. Part 3 – Signal processing; Transfer function; Active filters; Instrumentation amplifier; Noise; Digital signal processing.

295 pages — **Order code NE38** — **£41.00**

THEORY AND REFERENCE

THE AMATEUR SCIENTIST CD-ROM



The complete collection of The Amateur Scientist articles from Scientific American magazine. Over 1,000 classic science projects from a renowned source of winning projects. All projects are rated for cost, difficulty and possible hazards.

Plus over 1,000 pages of helpful science techniques that never appeared in Scientific American.

Exciting science projects in: Astronomy; Earth Science; Biology; Physics; Chemistry; Weather . . . and much more! The most complete resource ever assembled for hobbyists, and professionals looking for novel solutions to research problems.

Suitable for Mac, Windows, Linux or UNIX. 32MB RAM minimum, Netscape 4.0 or higher or Internet Explorer 4.0 or higher.

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OSCILLOSCOPES – FIFTH EDITION
Ian Hickman

Oscilloscopes are essential tools for checking circuit operation and diagnosing faults, and an enormous range of models are available.

This handy guide to oscilloscopes is essential reading for anyone who has to use a 'scope for their work or hobby; electronics designers, technicians, anyone in industry involved in test and measurement, electronics enthusiasts . . . Ian Hickman's review of all the latest types of 'scope currently available will prove especially useful for anyone planning to buy – or even build – an oscilloscope.

The contents include a description of the basic oscillscope; Advanced real-time oscilloscope; Accessories; Using oscilloscopes; Sampling oscilloscopes; Digital storage oscilloscopes; Oscilloscopes for special purposes; How oscilloscopes work (1): the CRT; How oscilloscopes work (2): circuitry; How oscilloscopes work (3): storage CRTs; plus a listing of Oscilloscope manufacturers and suppliers.

288 pages — **Order code NE37** — **£36.99**

ELECTRONIC TEST EQUIPMENT HANDBOOK
Steve Money

In most applications of electronics, test instruments are essential for checking the performance of a system or for diagnosing faults in operation, and so it is important for engineers, technicians, students and hobbyists to understand how the basic test instruments work and how they can be used.

The principles of operation of the various types of test instrument are explained in simple terms with a minimum of mathematical analysis. The book covers analogue and digital meters, bridges, oscilloscopes, signal generators, counters, timers and frequency measurement. The practical uses of these instruments are also examined.

206 pages — **Order code PC109** — **£9.95**

UNDERSTANDING ELECTRONIC CONTROL SYSTEMS
Owen Bishop

Owen Bishop has produced a concise, readable text to introduce a wide range of students, technicians and professionals to an important area of electronics. Control is a highly mathematical subject, but here maths is kept to a minimum, with flow charts to illustrate principles and techniques instead of equations.

Cutting edge topics such as microcontrollers, neural networks and fuzzy control are all here, making this an ideal refresher course for those working in Industry. Basic principles, control algorithms and hardwired control systems are also fully covered so the resulting book is a comprehensive text and well suited to college courses or background reading for university students.

The text is supported by questions under the headings Keeping Up and Test Your Knowledge so that the reader can develop a sound understanding and the ability to apply the techniques they are learning.

228 pages — **Order code NE35** — **£36.99**

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FULL COLOUR COMPUTING BOOKS

HOW TO FIX YOUR PC PROBLEMS — R.A. Penfold

What do you do when your laptop or desktop stops working properly. Do you panic, try to find the answer on the page of fault finding tips you may find at the back of the manufacturers manual. Or do you spend hours trying to get through to a telephone helpline or waste even more time waiting for an email reply from a helpdesk.

Well help is now at hand! This book will assist you in identifying the type of problem, whether it's hardware, software or a peripheral that is playing up? Once the fault has been identified, the book will then show you how to go about fixing it. This book uses plain English and avoids technical jargon wherever possible. It is also written in a practical and friendly manner and is logically arranged for easy reference.

The book is divided into four main sections and among the many topics covered are: Common problems with Windows Vista operating system not covered in other chapters. Also covers to a lesser extent Windows XP problems. Sorting out problems with ports, peripherals and leads. Also covers device drivers software and using monitoring software. Common problems with hard disc drives including partitioning and formatting a new drive. Using system restore and recovering files. Also covers CD-ROM and Flash drives. Common problems with sound and video, including getting a multi-speaker system set up correctly.

An extremely useful addition to the library of all computer users, as you never know when a fault may occur!

Printed in full colour on high quality non-refective paper

128 pages — **Order code BP705** — **£8.49**

AN INTRODUCTION TO WINDOWS VISTA — P.R.M. Oliver and N. Kantarris

If you have recently bought a new desktop or laptop it will almost certainly have Windows as its operating system. Windows Vista manages the available resource of a computer and also 'controls' the programs that run on it.

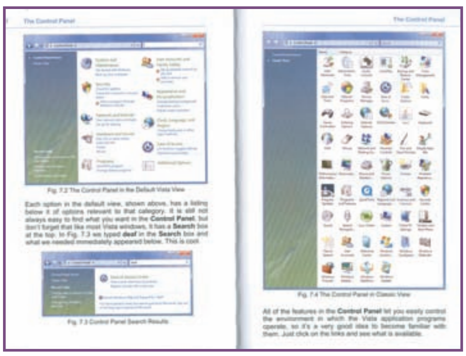
To get the most from your computer, it is important that you have a good understanding of Vista. This book will help you acheive just that. It is written in a friendly and practical way and is suitable for all age groups from youngsters to the older generation. It has been assumed that Vista is installed and running on your computer.

Among the numerous topics explained are: The Vista environment with its many windows. How to organise your files, folders and photos. How to use Internet Explorer for your web browsing. How to use Microsoft Mail for your emails. How to control your PC and keep it healthy. How to use Vista's Accessibility features if you have poor eye sight or difficulty in using the keyboard or mouse. And much more besides....

With the help of this book you will easily and enjoyably gain a better understanding of Microsoft's amazing Windows Vista operating system.

Printed in full colour on high quality non-refective paper

120 pages — **Order code BP703** — **£8.49**



COMPUTING WITH A LAPTOP FOR THE OLDER GENERATION — R.A. Penfold

Laptop computers have rapidly fallen in price, increased in specification and performance and become much lighter in weight. They can be used practically anywhere, then stored away out of sight. It is therefore, not surprising that laptop sales now far exceed those of desktop machines and that they are increasingly becoming the machine of choice for the older generation.

You may want to use your laptop as your main computer or as an extra machine. You may want to use your laptop on the move, at home, at work or on holiday. Whatever your specific requirements are, the friendly and practical approach of this book will help you to understand and get the most from your laptop PC in an easy and enjoyable way. It is written in plain English and wherever possible avoids technical jargon.

Among the many topics covered are: Choosing a laptop that suits your particular needs. Getting your new computer set up properly. Customising your computer so that it is optimised for your particular needs. Setting up and dealing with user accounts. Using the Windows 'Ease of Access Center'. Optimising the life and condition of your battery. Keeping the operating system and other software fully up-to-date. Troubleshooting common problems. Keeping your computer and data safe and secure. And much more besides...

Even though this book is written for the older generation, it is also suitable for anyone of any age who has a laptop or is thinking of buying one. It is written for computers that use Windows Vista as their operating system but much will still apply to Windows XP machines. Printed in full colour on high quality non-refective paper

120 pages — **Order code BP702** — **£8.49**

AN INTRODUCTION TO EXCEL SPREADSHEETS — Jim Gatenby

The practical and friendly approach of this book will help newcomers to easily learn and understand the basics of spreadsheets. This book is based on Microsoft's Excel 2007 spreadsheet, but much of the book will still apply to earlier versions of Excel. The book is written in plain English, avoiding technical and mathematical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Install the software. Use the exciting new features of Excel 2007. Create and use a spreadsheet. Enter, edit and format text, numbers and formulae. Insert and delete columns and rows. Save and print a spreadsheet. Present the information on a spreadsheet as a graph or chart. Manage and safeguard Excel files on disc. Use Excel as a simple database for names and addresses.

This book will help you to quickly gain confidence and get to grips with using spreadsheets. In fact, you will wonder how you ever managed without them.

Printed in full colour on high quality non-reflective paper.

118 pages — **Order code BP701** — **£8.49**

AN INTRODUCTION TO DIGITAL PHOTOGRAPHY WITH VISTA — R.A. Penfold

The friendly and practical approach of this book will help newcomers to digital photography and computing to easily learn the basics they will need when using a digital camera with a laptop or desktop PC. It is assumed that your PC uses Windows Vista, however, if it is a Windows XP machine the vast majority of this book will still apply. The book is written in plain English, avoiding technical jargon and all illustrations are in full colour. It is suitable for all age groups from youngsters to the older generation.

Among the many topics explained are how to: Understand the basic features of a digital camera. Transfer photographs from your digital camera to your computer. View your photographs. Save, sort and file your photographs. Manipulate, crop and carry out simple corrections to your photographs. Copy your photographs on to CD or DVD. Print your photographs. Share images with family and friends anywhere in the world by email or with an online album.

This book will help you quickly get to grips with, gain confidence and expand your horizons in the fascinating hobby of digital photography.

Printed in full colour on high quality non-reflective paper.

120 pages — **Order code BP700** — **£8.49**

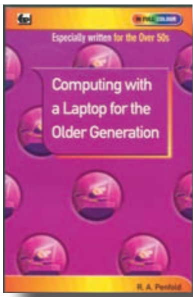
PROJECT BUILDING

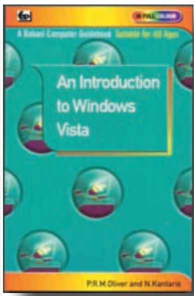
ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold
Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different.
The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

Temporarily out of print

BUILDING VALVE AMPLIFIERS
Morgan Jones
The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.
A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.
Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**





PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

HOW TO BUILD A COMPUTER
R.A. Penfold
To build your own computer is, actually, quite easy and does not require any special tools or skills. In fact, all that it requires is a screwdriver, pliers and some small spanners rather than a soldering iron! The parts required to build a computer are freely available and relatively inexpensive.
Obviously, a little technical knowledge is needed in order to buy the most suitable components, to connect everything together correctly and to set up the finished PC ready for use. This book will take you step-by-step through all the necessary procedures and is written in an easy to understand way. The latest hardware components are covered as is installing the Windows Vista operating system and troubleshooting.

320 pages **Order code BP591** **£8.99**

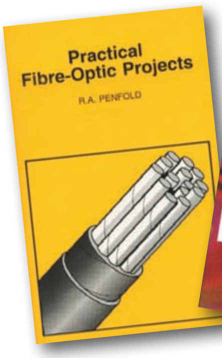
VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold
Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.
There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.
Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

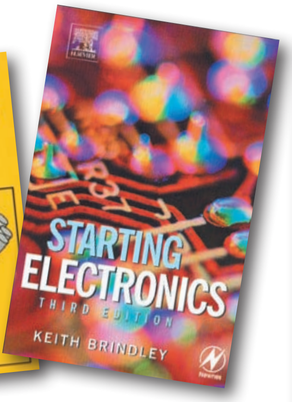
124 pages **Order code PC115** **£5.45**

THEORY AND REFERENCE

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages **Order code BP239** **£5.49**





STARTING ELECTRONICS
Third Edition
Keith brindley
A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.
A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.
Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

288 pages **Order code NE42** **£15.99**

BOOK ORDERING DETAILS

All prices include UK postage. for postage to Europe (air) and the rest of the world (surface) please add £2 per book. For the rest of the world airmail add £3 per book. **Note: Overseas surface mail postage can take up to 10 weeks**. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to:

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PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail. Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE	ORDER CODE	COST
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★ High-Accuracy Digital LC Meter – Main	745 } set	£8.73
– Adaptor	746	
– Shorting Bar	747	
2-way Stereo Headphone Adaptor	748	£11.33
★ Shift Indicator and Rev Limiter For Cars – Main	749 } set	£16.49
– Display	750	
APRIL '10		
USB Power Injector	597	£6.46
Alternative 12V 10A Power Supply	751	£7.88
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★ Water Tank Level Meter	753	£7.33
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Planet Jupiter Receiver (double-sided)	771	£15.00
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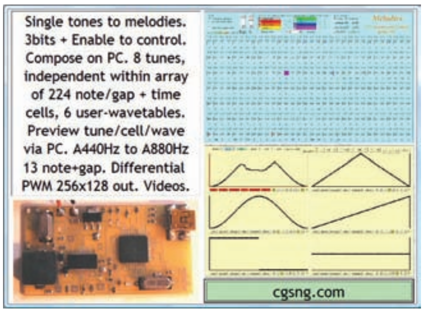

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Next Month

High Performance 230V AC 10A Full-Wave Motor Speed Controller

This full-range Motor Speed Controller gives silky smooth control from near zero to full speed on electric drills, routers, circular saws, lawn edgers, food mixers – in fact, any appliance with universal (brush-type) motors rated up to 2300W.

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Ever checked the calibration of your trusty digital multimeter? Probably not, there is no easy way of doing it. But now you can with this precision DC voltage reference that will provide you with a 10.000V DC source, accurate to within ±3mV (an accuracy of ±0.03%).

Build a 6-digit GPS clock – Part 2

Based on the GlobalSat EM-408 GPS module, this compact GPS receiver/ driver board mates with the 6-digit display described in this issue to form a self-contained GPS clock. It can also be housed separately and provide NMEA 0183 time / date data to a PC.

Musicolour IrDA Accessory

Add a wireless infrared port to last year's fascinating DSP Musicolour project – or in fact, virtually any microcontroller design.

Teach-In 2011 – Part 8

Mike and Richard Tooley continue our indispensable back-to-basic series with a look at some applications of analogue circuits, including filters and attenuators.

JUNE '11 ISSUE – ON SALE 5 MAY

Content may be subject to change

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